FISHERIES INVESTIGATIONS IN LAKES AND STREAMS

ANNUAL PROGRESS REPORT

Statewide Freshwater Fishery Research

July 1, 2015 - June 30, 2016

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Study Title: STATEWIDE FISHERIES RESEARCH

Job Title: Hydroacoustic Evaluation of Lake Wateree

Period Covered July 1, 2015 - June 30, 2016

Summary

A hydroacoustic survey and associated gill netting were conducted in September 2015 on Lake Wateree to estimate the density and abundance of the pelagic fish community. The hydroacoustic survey transect covered 20 km, from just above the Lake Wateree dam to Wateree State Park. The average hydroacoustic estimate was 92,597 fish (less than 60 cm total length)/ha. Threadfin shad *Dorosoma petenense* comprised 85.8% of the gill net catch and 99.1% of the catch of fish ≤ 15 cm total length. Hydroacoustic length frequency data indicated that fish ≤ 15 cm total length made up 98.9% of the total fish community. These combined results strongly suggest that threadfin shad comprised the vast majority of the density estimate for Lake Wateree. In the coming year, a biomass/ha estimate will be generated.

Introduction

To understand fish population dynamics in Lake Wateree, knowledge of the density (number/ha), standing crop (kg/ha), species composition and production of the forage base is essential. Hydroacoustic technology, newly acquired by the Section, allows these estimates to be made. Preliminary sampling on the Santee-Cooper lakes with hydroacoustics in 2010 verified that the use of this technology was practical and efficient. This report summarizes an initial survey and the results obtained from Lake Wateree, a productive, 5,548 ha impoundment in north central South Carolina.

Materials and Methods.

Hydroacoustic and concurrent gill net sampling of Lake Wateree were conducted on the evening of September 8 and the early morning of September 9, 2015. Hydroacoustic soundings were taken along a single, 20 km long, transect that started just upstream of the dam (34.3427, -80.7062) and finished in the vicinity of Wateree State Park (34.4349, -80.8535); the transect followed the historic river channel (Figure 1). Maximum depth was 18 and 10 m at the dam and Wateree State Park, respectively. The hydroacoustic transects was initiated at 10:15 PM (EDT), 90 minutes after sunset.

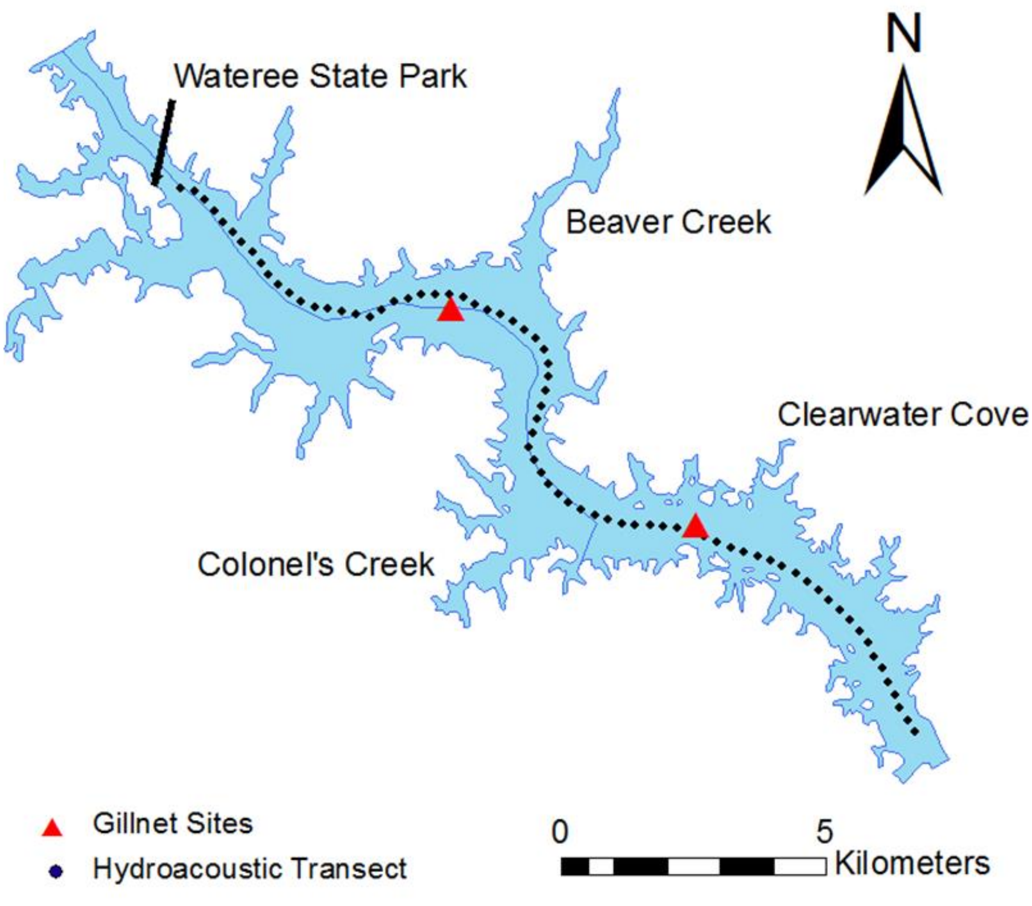

Figure 1. Map of the Lake Wateree, South Carolina, hydroacoustic and gill net study sites.

We used a BioSonics (Seattle, Washington) DT-X echo sounder and two, 200-khz split beam, 6 degree transducers to obtain hydroacoustic data. Transducers were set to ping at 10/second with a 0.2 millisecond pulse duration. Surface data was collected from the surface to a depth of 2 m with a transducer deployed 1 m below the surface and aimed parallel to the surface. Sub-surface data was collected with a transducer deployed 0.5 m below the surface and aimed perpendicular to the surface of the lake. Echo integration parameters were set to process surface data 1 to 20 m from the transducer while sub-surface parameters were set to process data from 2 m below the surface to 0.25 m above the bottom. During collection of hydroacoustic data, a new data file was created every 250 m, allowing inspection of the variability in fish abundance along the sampling transect. Prior to sampling, the unit was calibrated with a 420 kilohertz calibration sphere.

Digital files from the completed transects were sent to an outside contractor, Aquacoustics Inc. (Sterling, Alaska), for processing and analysis. The contractor estimated abundance and size through single target strength analysis and echo integration. Echoview software (Tasmania, Australia) was used to analyze all data. Hydroacoustic data was manually edited to remove bottom signals, such as submerged trees, or noise. Fish target lengths were derived by converting target strength to fish length via Love's (Love 1971) dorsal aspect equation. Fish targets greater than 60 cm in length were edited from the final data set.

Gill net sampling was conducted concurrently with hydroacoustic transects. A 1.83 m deep experimental gill net with 4.57 m sections of 6.35, 9.53, 12.70, 15.88, and 19.05 mm bar mesh was used. Gill nets were set on the surface (floating) and on the bottom and were set at two distinct sites along the hydroacoustic transect: 1) above Clearwater Cove (34.3767, -80.7499) and 2) above Beaver Creek (34.4134,-80.7999) (Figure 1).

Results and Discussion

Gill net surveys indicated that threadfin shad were the dominant species in Lake Wateree. A total of 388 fish were collected, 228 at the Clearwater cove site and 160 at the Beaver Creek site. Threadfin shad comprised 85.8% (N=333) of the catch and white perch *Morone americana* were 10.6% (N=41). Threadfin shad ranged in total length from 46 to 153 mm while white perch ranged from 157 to 259 mm. Other species collected were blue catfish *Ictalurus furcatus* (N=9), channel catfish *Ictalurus punctatus* (N=2), gizzard shad *Dorosoma cepedianum* (N=2), and black crappie *Pomoxis nigromaculatus* (N=1). Substantially more fish were caught in the floating net, which accounted for 92.8% of the catch, than the sinking net.

Hydroacoustic transects indicated that the average density of fish was 92,597/ha (95% confidence interval = ± 9,227). Eighty-four, 250 m sub-samples were taken along the hydroacoustic sampling transect. Fish densities increased in the up-lake portion of the transect, from approximately sample 40 (34.3886, -80.7831), located between Colonel's Creek and Beaver Creek, to the final sample (i.e. 84) at Wateree State Park (Figure 2). Fish ≤ 15 cm total length, comprised 98.8% of the hydroacoustic targets (i.e. fish), suggesting, based on gill net length frequency results, that threadfin shad were the vast majority of fish encountered during the survey. On average, 84% of the fish were recorded by the down-looking transducer.

The average density of fish recorded in Lake Wateree of 92,597/ha was over four times higher than the average density of 21,363/ha that Bulak (2016) reported in lakes Marion and Moultrie, 2013-2015. This result was expected as historic evaluations consistently showed that Lake Wateree was one of the most productive reservoirs in South Carolina. In the coming year, a weight will be assigned to the fish targets so that the standing crop of pelagic, forage fishes in Lake Wateree can be calculated and compared to historic estimates obtained through cove rotenone.

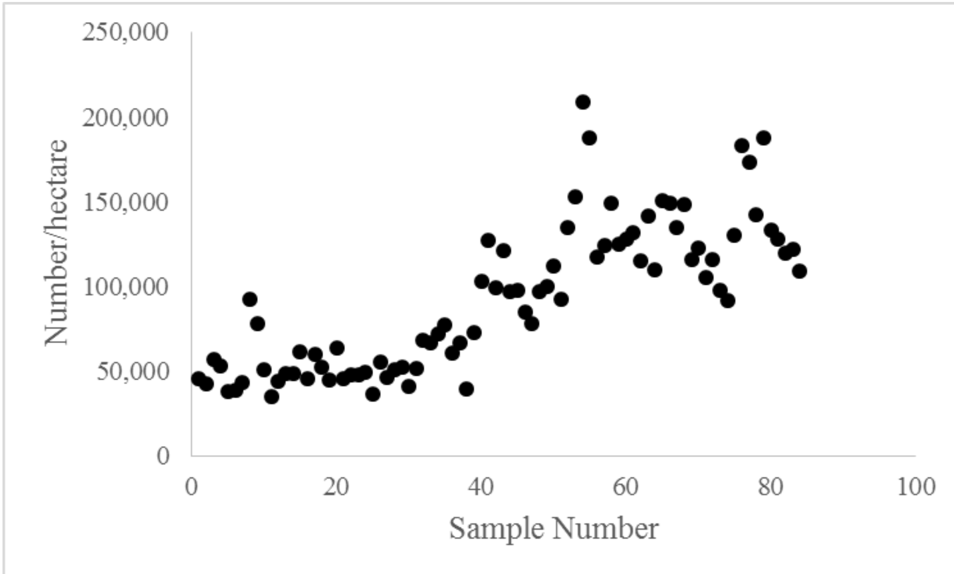

Figure 2. Density of hydroacoustic targets along a 20 kilometer transect in Lake Wateree, South Carolina. Samples were taken every 250 meters along the study transect.

Recommendations

1. Convert density estimates to standing crop estimates in the coming year.
2. Compare hydroacoustic obtained standing crop results to historic estimates obtained through cove rotenone.

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Love, R.H. 1971. Dorsal aspect target strength of an individual fish. Journal of the Acoustical Society of America 62:1397-1403.

Prepared By: James Bulak Title: Research Coordinator - Freshwater Fisheries

Job Title: Lake Hartwell Habitat Evaluation

Period Covered July 1, 2015 - June 30, 2016

Summary

Using mark and recapture methods and telemetry, a population estimate of catchable (> 304 mm, total length) Largemouth Bass *Micropterus salmoides* was obtained from two relatively large (approximately 35 hectares), non-habitat enhanced embayments of Lake Hartwell. Population estimates 179 and 102 catchable bass were obtained from the two study embayments. Compared to a pilot study performed in 2013 on one, habitat-enhanced cove, telemetry showed that a smaller percentage of fish remained on the shoreline and were vulnerable to electrofishing during the study period; migration from the study embayment was higher than observed in 2013.

Introduction

Lake Hartwell, impounded in 1963, is a 22,600 hectare U.S. Army Corps of Engineers reservoir located in the Savannah River basin. The presence of polychlorinated biphenyls (PCB) in the Twelve Mile Creek arm of Lake Hartwell was discovered in the 1970s; this led to a legal action and, eventually, a monetary settlement with the plaintiffs by the responsible party. South Carolina elected to use a part of these settlement monies to enhance the habitat of Lake Hartwell, which is done by placing various structures (such as fallen trees, gravel beds, and root wads) in the reservoir. Habitat placement occurs to enhance angler success and the local biological production potential. However, it is not clear how much increase in biological production will occur as a result of habitat placement. Thus, this year's objective was to use telemetry and mark and recapture techniques to estimate the population size of catchable Largemouth Bass on each of two study embayments, neither of which had received any purposeful habitat enhancement efforts.

In future years, these estimates would serve as a baseline to assess the effects of habitat enhancement efforts.

Materials and Methods.

Two study site embayments were chosen that were just south of the West Cherry Road bridge crossing, Clemson, South Carolina. (Figure 1). The first embayment, termed the “AM cove,” contained the Twin Lakes Recreation Area boat landing, was 32 hectares, and was located at 34.61993, -8284951. The second embayment, termed the “PM cove,” was west of the AM cove, 36 hectares, and located at 34.62225, -82.87314. Neither cove had received any purposeful habitat enhancement.

Figure 1. Map of the 36 and 32 hectare study embayments on Lake Hartwell, in the vicinity of Clemson, South Carolina.

A strategy that combined a traditional mark and recapture approach with telemetry was chosen. Mark and recapture was expected to provide a population estimate with a reasonable degree of statistical certainly. Telemetry was used to assess migration and define the portion of the population that was vulnerable to the chosen sampling gear, boat electrofishing. Fish present in locations ≥ 2.44 m in depth were defined as not vulnerable to electrofishing.

Sixteen (16) LMB were captured with boat-mounted electrofishing equipment and surgically implanted with transmitters in each, study cove. When Largemouth Bass were captured they were immediately placed on a large v-trough measuring board, covered with wet towels, and measured (TL mm). Ultrasonic transmitters were inserted through a 30 mm incision posterior to the right ventral fin. Incisions were closed with two or three interrupted absorbable sutures (2-0 Maxon; Tyco Health Care). No chemical anesthesia was used; the fish were sufficiently sedated by electrofishing for the short (<120 sec) implantation procedure. Mean total length of fish implanted in the AM cove was 404 mm (range; 321 – 530 mm) and mean total length in the PM cove was 400 mm TL (range; 316 – 503). IBDT-96-2 transmitters (Sonotronics, Tucson, AZ) were used on fish from 316 to 370 mm total length and CT-82-1 transmitters (Sonotronics, Tucson, AZ) were used on fish 360 to 530 mm total length; both transmitters has an advertised battery life of 60 days.

Transmitter-implanted Largemouth Bass were monitored with an acoustic receiver array and by manual tracking. An array of 16 remote acoustic receivers (SUR3BT, Sonotronics, Inc., Tucson, Arizona) was deployed at or near the mouth of and within the two study coves in March, 2016, to monitor emigration of Largemouth Bass from the study coves. Largemouth Bass were manually located by boat during the daytime using a scanning receiver and hydrophone (USR08, Sonotronics, Inc., Tucson, Arizona), to determine whether or not they occupied the shoreline and as such were in water depths (< 2.44 m) vulnerable to electrofishing. The coves were manually tracked the day before planned electrofishing for the mark-recapture portion of the study. The entire area of each cove was tracked systematically and all possible frequencies were scanned. Once each fish was located, its transmitter ID, location, estimated depth, and notable occupied habitat structures were noted. The AM cove was monitored in the morning and PM cove in the afternoon. Once fish were located their depths and positions were recorded. Depths were recorded from the onboard depth finder.

For the mark-recapture portion of the study, Largemouth Bass > 304 mm TL were captured along the shoreline of each cove using boat electrofishing. At the first sampling event, length and weight were measured and a uniquely-numbered PIT tag was inserted into the abdominal cavity. On subsequent sampling trips, the same protocol was followed and each captured fish was checked for the presence of a PIT tag using a portable detector. The AM cove was sampled in the morning and PM cove in the afternoon.

A dynamic occupancy formation of individual capture histories combined with a data augmentation technique (Kéry and Schaub 2012; Royle and Dorazio 2012) was used to estimate the population size of catchable Largemouth Bass. Telemetry data was used to assess the proportion of the population that was within shoreline habitat and the amount of migration out of or into the cove, both of which influenced the vulnerability of tagged fish to the sampling effort and, thus, the accuracy of the population estimate.

Results and Discussion

Manual tracking of transmitted Largemouth Bass was conducted on three days between April 15 and 21, 2015. Fifty (50) observations of presumed live fish were made. The number of live fish located by tracking event (cove x date) ranged from 7 to 11. The portion of the detected fish that were in < 2.44 m of water ranged from 36 to 100%, varying widely among the six tracking events (Table 1).

Table 1. The number of transmitted largemouth bass that were located by manual tracking and deemed vulnerable to electrofishing (i.e. depth < 2.44 m) in two, Lake Hartwell, South Carolina embayments.

Date (2016)	Embayment	Number located	Number vulnerable
April 15	AM	6	6
April 15	PM	11	4
April 19	AM	7	6
April 19	PM	6	4
April 21	AM	7	4
April 21	PM	6	3

Of the 32 fish that were transmitted, remote receivers indicated that 16 remained in the study embayments during the mark-recapture experiment. Of those not remaining, 11 had left the study area, three were harvested, one died, and one had a faulty transmitter. Of the 16 transmitted fish remaining in the study coves during the mark-recapture sampling days, 14, 15, and 14 were available (in the study embayments) during the first, second, and third days of mark-recapture sampling. One fish migrated from the AM to the PM cove where it was available on 2 of the 3 mark-recapture sampling dates. Movement from the embayments to the main channel of the lake (i.e. out of the study zone) and back into the embayments was fairly common.

During three days of mark-recapture sampling, 145 (AM cove) and 105 (PM cove) unique individuals of catchable Largemouth Bass (> 300 mm in TL) were captured and given uniquely numbered PIT tags. On the two days of sampling when recaptures were available, 25 (PM cove) and 21 (PM cove) recaptures of PIT tagged fish were made; two transmitted fish were also recaptured.

The population size of catchable Largemouth Bass in the shoreline habitat was estimated at 179 catchable bass (95% Confidence Interval (CI): 107-276) in the AM cove and 102 fish (95% CI: 59-162) in the PM cove. The estimates indicate that the AM cove had a larger population of catchable bass than the AM cove. Observations indicated there was more habitat in the AM cove, mainly in the form of boat docks, around which fish were generally observed.

The population estimates obtained in this study were less than the estimate of 230 obtained on the habitat-enhanced cove in 2015. However, this study was done slightly later in the year than in 2015. Water temperatures were higher and migration to and from the coves was greater, perhaps indicating the evaluated population evaluated in 2016 was in a more transient state than the 2015 population. But, this effort does provide a baseline estimate of population size for non-enhanced coves in this area of Lake Hartwell. Future studies should replicate this study and, in time, enhance habitat and repeat the study.

Recommendations

1. Finalize the 2016 population estimates and present results at an upcoming scientific meeting.
2. Using 2016 results and experience identify a work strategy for 2017 that maximizes accuracy and efficiency
3. Evaluate whether the current confidence intervals are adequate to meet long-term study objectives.
4. Plan to, at least, replicate the telemetry and mark/recapture evaluation in the same coves in 2017, considering an additional cove if resources are available.

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Kéry, M., and M. Schaub. 2012. Bayesian population analysis using WinBUGS: A hierarchical perspective. Elsevier, New York.

Prepared By: James Bulak Title: Research Coordinator - Freshwater Fisheries

Job Title: Redbreast Stocking Evaluation – Edisto River

Period Covered July 1, 2015 – June 30, 2016

Summary

An evaluation of the stocking of redbreast sunfish *Lepomis auritus* on the Edisto River was initiated in FY 2011 and continued through FY 2016. In the last year ageing and mark evaluations were completed on fish collected from the 2013 year class. Fish were collected from eight prescribed zones which include two zones immediately upstream of the stocking area, four within the stocking area, and two zones immediately downstream. Overall 11 of 126 fish evaluated, or 9%, were marked. All marked fish collected were either from one of the two middle zones within the stocked area, or from the closest downstream zone.

Mark evaluations were completed on known marked redbreast sunfish from the 2015 year class and all exhibited marks. Evaluation of a blind set of otoliths is in process. Redbreast sunfish were collected from the Edisto River during Spring 2016 by Region 3 staff, and age estimations of whole ototliths were begun to identify fish from the 2014 and 2015 year classes. Once aged, individuals from the year classes of interest will be mounted, sectioned and processed for oxytetracycline (OTC) mark determination.

Introduction

Redbreast sunfish is a much sought after sport fish on the Edisto River. This is evidenced in collections made in 2004 that spanned a very high water event. Those collections suggest that once hydrologic conditions normalized, allowing for greater river access and angling, larger fish were quickly exploited and removed (Bulak 2005). The annual stocking of the Edisto River with redbreast sunfish began in 1995. This was in response to public concerns that introduced flathead catfish *Pylodictis olivaris* were negatively impacting the popular fishery. Records show approximately 13.7 million redbreast stocked in the river since 1995, with annual stocking ranging from 0.45-2.2 million.

The supplemental stocking of redbreast sunfish in Edisto River has never been evaluated. Collections of microtagged redbreast sunfish that were stocked in Little Pee Dee River from 1990–1992 suggested minimal contribution, though further sampling was recommended before drawing conclusions from the available data (Crochet and Sample 1993). Genetic survey of redbreast sunfish populations across five South Carolina drainages indicated Edisto River redbreast were markedly less diverse than redbreast populations from other drainages (Leitner 2006). This could be a result of lost diversity in the former hatchery population and its impact on the receiving population in the river, or could be an indication of bottleneck events occurring in the wild. To best manage this resource, we need a basic understanding of whether supplemental stocking is contributing to the redbreast sunfish population and fishery of the Edisto River. In the last year, a mark evaluation of known marked fish from the 2015 year class was conducted, and hatchery contribution to the 2013 year class was evaluated.

Materials and Methods

In FY 2014, fish were collected by boat electrofishing from the Edisto River to target the 2013 year class at Age 1. Fish were collected from eight contiguous but separate zones. They are from upstream to downstream, Upper Zones 2 and 1 (U2, U1), Stocking Zones 1, 2, 3, and 4 (S1, S2, S3, S4), and Downstream Zones 1 and 2 (D1, D2). Oxytetracycline evaluation of these otoliths was begun in FY 2015 and completed in the last year. Otoliths from fish estimated to be Age 1 were processed according to standard procedures for OTC mark evaluation. Mark presence or absence was evaluated by two independent readers. Fish that were not readable or that readers disagreed on were not included in final analysis. Hatchery contribution as a proportion of total collection was computed by collection zone, and overall.

Plans to collect redbreast sunfish from the 2014 year class were postponed due to very high water through the Fall and Winter of 2015. Boat electrofishing collections were completed for each of eight sampling zones by Region 3 April 20 to May, 26, 2016. Otoliths were removed from all fish collected. Prior to the start of ageing, staff consulted with Region 3 regarding potential difficulties in ageing of fish collected in the Spring. Ageing is in process now by Region 3 staff. Once completed, aged samples from the 2014 and 2015 year classes will be provided to this lab for OTC mark determination.

Marks for the 2014 year class of hatchery produced fish were evaluated and reported on in FY 2015. In the last year we evaluated nine known marked fish from three mark events from the 2015 year class. We also produced a blind set of known marked and unmarked 2015 year class fish and this evaluation is in process.

Results and Discussion

A total of 133 fish collected in FY 2014 were estimated to be from the 2013 year class and were evaluated for marks. Of these, seven were determined to be unreadable by one or both readers and were not included in the final evaluation. Of 126 remaining otoliths 11, or 9 %, were marked. Marked fish were collected from zones S2, S3 and D1, with proportions of stocked fish within those zones ranging from 7% – 24% (Table 1). Similar results were obtained in 2010 when stocked fish comprised 9% of the total sample, and 14% of fish collected from the stocking zone.

Table 1. Marked and unmarked 2013 year class Redbreast Sunfish collected from the Edisto River October 2014.

Collection Zone	Total 2013 yc collected	N unmarked	N marked	Proportion marked
Upstream 2	3	3	0	0
Upstream 1	19	19	0	0
Stock 1	16	16	0	0
Stock 2	21	16	5	0.24
Stock 3	14	13	1	0.07
Stock 4	14	14	0	0
Downstream 1	33	28	5	0.15
Downstream 2	6	6	0	0
Total	126	115	11	0.09

All 2013 year class fish collected from zones upstream of S2 were unmarked. Similarly when the 2010 year class was assessed no marked fish were collected from further upstream than S1 (Figures 1 and 2), indicating stocking may be unlikely to provide even minimum contribution upstream of areas where fish are released.

All nine known marked fish evaluated from the 2015 year class were well marked. Positive results were obtained from evaluation of known marked fish in 2014 as well.

<u>Recommendations</u>

Complete study. Finish blind set evaluation of known marked and unmarked fish from 2015 year class. Complete ageing and mark evaluations of 2014, and potentially 2015 year classes. Make recommendations based on results of this study regarding the continued stocking of redbreast sunfish

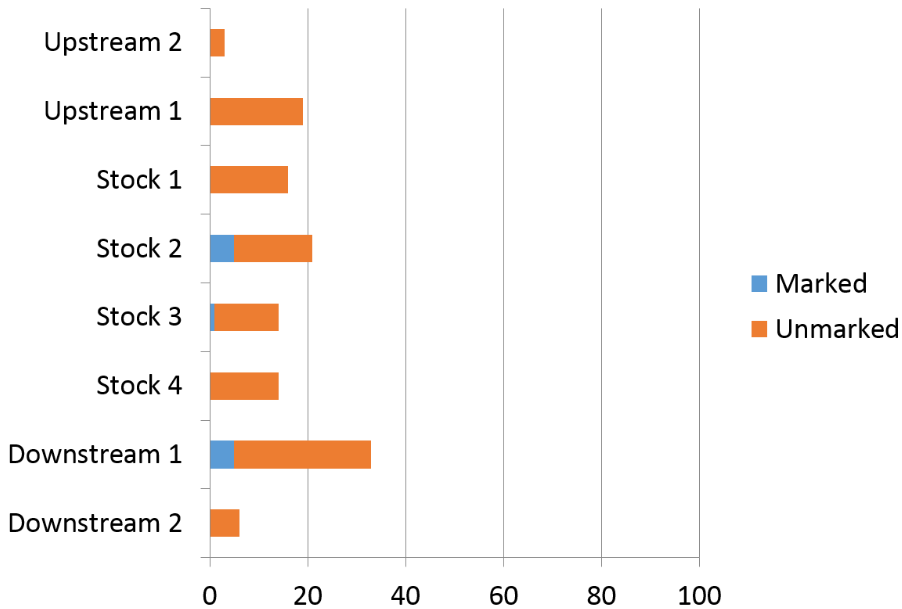

Figure 1. Numbers of marked and unmarked redbreast sunfish (N = 126) collected from the Edisto River in 2013, by collection zone.

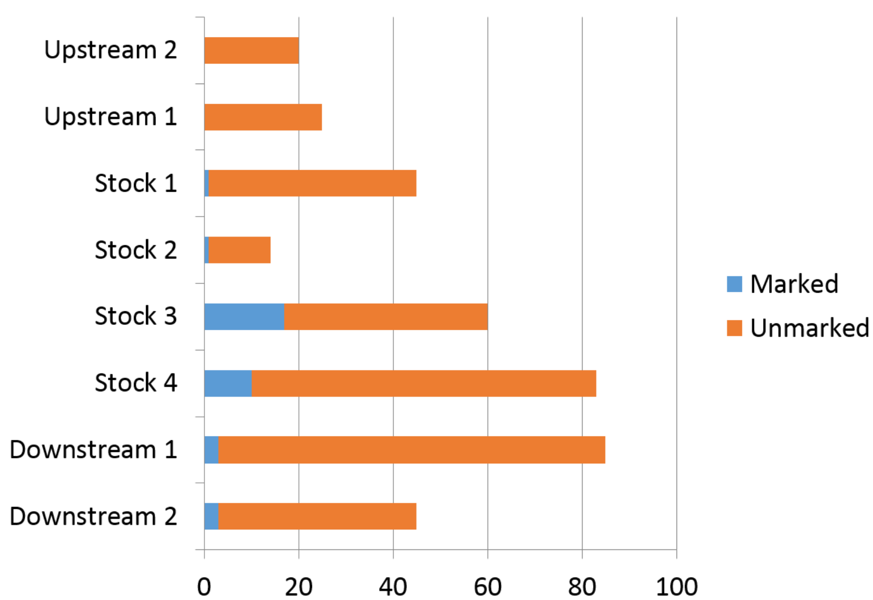

Figure 2. Numbers of marked and unmarked redbreast sunfish (N = 377) collected from the Edisto River in 2010, by collection zone.

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Leitner, Jean. 2006. Zoogeography of Centrarchidae of the Atlantic Slope. Study Completion Report. South Carolina Department of Natural Resources.

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Prepared By: Jean Leitner Title: Biologist

Job Title:	Assessing introgressive hybridization within and habitat requirements of native South Carolina redeye bass
Period Covered	July 1, 2015 – June 30, 2016

Summary

Work continued on the study of redeye bass *Micropterus coosae* (Hubbs and Bailey 1940) and impacts of hybridization with introduced Alabama bass *Micropterus henshalli*. Genetic assay development was completed. Fish collections and instream habitat assessments were completed for sites throughout the Savannah Basin, including sites on the Broad River, and South Fork Broad River on the Georgia side of the basin. Genetic analysis was completed for all fish collected and is reported on here. While hybrids were collected from all sites sampled on Little River and Twelvemile Creek, other rivers supported genetically pure populations of redeye bass. On Chauga and Chatooga rivers hybrids were largely limited to downstream locations in closest proximity to reservoirs. In the last year South Carolina Department of Natural Resources was awarded $82,290 for the expansion of this work. Continued efforts will include expanded survey work and model development to predict areas of the Savannah basin that support pure redeye populations. Work will move forward in close cooperation with related efforts to be undertaken at Clemson University, including a spawning study.

Introduction

The redeye bass is one of two black bass native to South Carolina, and has been identified by South Carolina's Comprehensive Wildlife Conservation Strategy as a Species of Highest Priority due its restricted range and threats from introduced species (Kohlsaat et al. 2005). In South Carolina the species' native range is restricted to the Savannah Basin above the Fall Line. Redeye bass occupy habitats in cool-water streams (Rhode et al. 2009) and in addition have historically thrived within four of the Savannah River basin's man-made reservoirs; Jocassee, Keowee, Hartwell and Russell (Koppelman and Garret 2002).

Recent studies examined the relationship among populations of redeye bass across the range of the species. Mobile Bay drainage redeye bass are morphologically distinct from Atlantic Slope populations, with the common name Bartram's bass assigned to the latter (Freeman et al. 2015). DNA sequence data supports this distinction, and further suggests species-level divergence between Savannah River redeye bass and those of other Atlantic Slope drainages (Oswald 2007; Freeman et al. 2015). Savannah River redeye bass represent a highly divergent and distinct evolutionary lineage, and is one of three focus species in the National Fish and Wildlife Foundation's Native Black Bass Initiative (Birdsong et al. 2010).

Introductions of the non-native Alabama bass into lakes Keowee and Russell have put Savannah River redeye bass at risk due to introgessive hybridization (Barwick et al. 2006). Genetic surveys in 2004 and 2010 showed that Alabama bass have expanded within the drainage, as have their hybrids with redeye bass (Leitner et al. 2015). Both are present in all four lakes surveyed, and in 2010 together they comprised from 48% to 68% of black bass collected from each reservoir (Bangs et al. 2015). The survey of tributaries of the drainage indicated in 2004 that those redeye populations were for the most part still unimpacted by hybridization, but in 2010 an increase in Alabama bass alleles was noted for several tributaries (Leitner et al. 2015). Alabama bass are known to take advantage of stream habitats, and the continued spread of their alleles throughout the drainage is a possibility.

Materials and Methods

Work has continued on the study of redeye bass in South Carolina, the impacts of hybridization among black bass species on redeye populations, and associated outreach efforts.

Work in the last year has focused on completion of development of new fast genetic assays to identify black bass and hybrids, a longitudinal genetic assessment of redeye bass tributary populations using those assays, and collection of associated habitat and landscape data.

The initial objective in assay development was to, using hydrolysis probe technology, develop and characterize single-copy nuclear gene assays for three loci that differentiate Alabama bass, redeye bass and their hybrids. Sequence information implicit in Oswald (2009) was used to develop these targeted assays and was successful for two loci, B-actin and Calmodulin. However, hydrolysis probe development for the ITS locus was unsuccessful. To circumvent issues caused by a high GC rich content of ITS, in the last year newly optimized CTPP (Confronting Two-Pairs Primers) software (Chuang et al. 2015; http://bio.kuas.edu.tw/ma-ctpp/availability.jsp) was used to design sets of amplification primers. These primers were tested against a set of 12 previously sequenced individuals, 4 each of Alabama bass, redeye bass and hybrids.

We continued to coordinate with Region 1 and with outside partners in the collection of data for the establishment of genetic and habitat baselines. Population sampling in the last year has focused on completing needed fish collections from sites in the Savannah Basin. Collection sites were chosen to provide a longitudinal perspective for each stream. Collections were made by backpack or boat electrofishing where conditions were suitable for such, and by angling at other sites. All bass collected were measured (total length) and field identified to species. Fin clips were taken and provided to USC for genetic analysis at three nuclear and one mitochondrial loci. Proportions of redeye bass individuals, alleles (nDNA), and haplotypes (mtDNA) were determined for each site.

At sites that could be waded, the 'zig zag' method was used to determine current velocity, depth and substrate as described in the South Carolina Stream Assessment Standard Operating

Procedures (M. Scott et al. 2009) adapted from Bevenger and King (1995). Separate measurements (N=50) were conducted at each 100-m site utilizing a flow meter, top-set wading rod, and meter stick. Starting at the beginning of each site (0-m), measurements were taken at various locations along the stream reach in a zig-zag manner to proportionally represent multiple stream habitats (i.e. riffle, run, pool). At each of the 50 points selected, depth was measured (m) and water velocity (m/s) was taken using a flow meter and staff at 0.6 depth. Bottom substrate was blindly selected as the first object touched, categorized by the measurer and recorded. Substrate was then categorized by type (inorganic or organic) and size, and recorded. Every 20 m, wetted channel width was taken starting at zero meters using a range finder for a total of six width measurements within the 100 m reach. 'Deep' habitat was defined as ≥ 1.5 m. Length and width of deep sections were measured using a laser rangefinder. Using mean river widths (N=6) in conjunction with river reach sampled (100m), total percentage of deep habitat was determined using the equation: Total deep patch (m^2)/Total area of transect (m^2) *100. Habitat data from sites that could be waded, as well as land use data for all sites, will be related back to bass hybridization metrics.

Results and Discussion

Amplification primers designed for the ITS locus were successful at diagnosing Alabama bass, redeye bass and their hybrids. After optimization of PCR conditions, all control individuals assayed were identified correctly. This set of CTPP primers was used in the final analysis of all fish collected.

Redeye bass and/or their hybrids with Alabama bass were collected and analyzed from five sites on Steven's Creek in South Carolina (N = 31). Bass were also collected from four sites in the Broad River portion of the basin in Georgia. On the Broad River's South Fork, fish were collected from a site just below the dam at Watson Mill State Park, and from a closely positioned site on its tributary Clouds Creek which enters just downstream from Watson Mill Dam (combined N = 21). Collections from sites of interest on the main stem of the Broad River were largely unsuccessful, despite multiple attempts using various gears. However we did collect and analyze some bass from Anthony Shoals (N = 3) near the river's entrance to Lake Thurmond, and from a site 37 miles upriver at Sandbar Kayak and Zipline (N = 9; Table 1.).

All collected fish were provided to USC for genetic analysis, and a final data set including all sites was recently received. Hybrids were collected throughout Twelvemile Creek (60 – 100%) and Little River (27 – 46%), while all but the lower most sites on Chauga River, Chatooga River, and Eastatoee Creek produced 95 - 100% pure redeye bass. No hybrids were collected from Steven's Creek, or from either site at Watson Mill State Park associated with South Fork Broad River. For the main stem Broad River sites, two of three fish collected at Anthony Shoals, near the rivers entrance to Lake Thurmond, were hybrids while all nine fish collected from approximately 37 river miles upstream were redeye. For most rivers where hybrids were present, they were most prevalent at the lowermost sampling sites (Table 1). The exception is Twelvemile Creek, where hybrids were found throughout the stream at varying proportions.

Table 1. Genetic results for redeye bass and their potential hybrids collected from Savannah basin streams. Stream sites for each Sub Basin / Stream are ordered downstream to upstream. 'SPP' denotes the proportion of redeye bass in each sample. Nuclear (nDNA) and mitochondrial DNA (mtDNA) proportions are numerical proportions of alleles or haplotypes specific to redeye bass, across all individual redeye, Alabama, and hybrid bass collected.

Sub Basin / Stream	Site	N Fish	Proportion REB		
			SPP	nDNA	mtDNA
Tugaloo River					
Chatooga	Tugaloo-Opossum Creek	4	0.50	0.71	0.75
	Hwy 76	31	1.00	1.00	1.00
	Camp Creek	29	0.96	1.00	0.97
Chauga	Jenkins Bridge	13	0.61	0.80	1.00
	Chau-Ram	21	0.95	0.95	1.00
	Cobb Bridge	23	1.00	1.00	1.00
	Riley Moore	45	1.00	1.00	1.00
Seneca River					
Eastatoee Creek	Eastatoee Baptist Church	18	0.89	0.98	1.00
	Hemlock Hollow	1	1.00	1.00	1.00
Little River	Lower - Burnt Tanyard	24	0.54	0.76	0.92
	Middle - Trombley	38	0.58	0.86	1.00
	Upper - Williams	15	0.73	0.94	1.00
Twelvemile	Below Easley Central Dam	5	0.40	0.70	1.00
	Liberty Highway	3	0.00	0.22	0.67
	Robinson Bridge	20	0.35	0.68	0.90
	Souliri	14	0.07	0.62	0.93
	Stewart Gin	8	0.13	0.56	0.75
Savannah River					
Broad River, GA	Anthony Shoals	3	0.33	0.78	0.33
	Sandbar Kayak and Zipline	9	1.00	1.00	1.00
Big Clouds Creek, GA	Watson Mill State Park	6	1.00	1.00	1.00
South Fork Broad River, GA	Watson Mill State Park	15	1.00	1.00	1.00
Stevens Creek	At 88	1	1.00	1.00	1.00
	At 23	2	1.00	1.00	1.00
	Upstream of Turkey Creek	2	1.00	1.00	1.00
	At Parksville	3	1.00	1.00	1.00
	At 21	23	1.00	1.00	1.00

Stream habitat assessment was conducted between September 2015 and June 2016 at 12 separate sampling sites on the following South Carolina Rivers: Eastatoee River, Stevens Creek, and Little River. Two sites were also included from Georgia: Clouds Creek and South Fork of the Broad River (Watson Mill Bridge). Results for assessments at these sites as well as for sites assessed previously on Twelvemile Creek are included in Table 2. These instream habitat data, as well as catchment data for all sites, will be related to proportions of redeye bass and hybrids.

Table 2. Calculated habitat variables by sample location, with mean and median values for each stream; Twelvemile Creek, Eastatoee Creek, Little River, Steven's Creek, Big Clouds Creek, GA and South Fork Broad River, GA.

	mean depth	depth SD	mean velocity (m/s)	velocity SD	median substrate (mm)	mean width (m)	% Large Woody Debris	% deep habitat
Liberty Highway	0.42	0.16	0.25	0.13	1.00	19.42	20.00	0.00
Stewart Gin	0.48	0.18	0.37	0.23	2.00	12.00	4.00	0.00
Allgood Bridge	0.39	0.17	0.35	0.18	1.00	12.92	12.00	0.00
Belle Shoals	0.49	0.20	0.26	0.13	1.00	14.00	12.00	0.00
Easley Central	0.34	0.17	0.46	0.29	3.00	30.83	0.00	0.00
Robinson Bridge	0.42	0.12	0.34	0.19	0.50	17.00	22.00	0.00
Souliri	0.39	0.18	0.34	0.30	5.00	21.75	2.00	0.59
12 Mile	0.42	N/A	0.34	N/A	1.93	18.27	10.29	0.08
Hemlock Hollow	0.41	0.16	0.30	0.24	47.00	14.67	0.00	0.00
Eastatoee Church	0.39	0.23	0.37	0.25	25.00	10.75	4.00	5.21
Eastatoee	0.40	N/A	0.34	N/A	36.00	12.71	2.00	2.60
Burnt Tanyard	0.51	0.23	0.29	0.24	999.00	31.25	2.00	15.46
Doc Tromley	0.36	0.18	0.27	0.28	999.00	19.50	0.00	1.23
Williams	0.46	0.19	0.25	0.21	41.00	17.58	0.00	8.42
Little River	0.44	N/A	0.27	N/A	679.67	22.78	0.67	8.37
88 Highway	0.36	0.21	0.06	0.11	2.00	13.17	20.00	0.00
Highway 23	0.54	0.17	0.00	0.01	999.00	22.80	4.00	0.00
Highway 21	0.33	0.16	0.06	0.13	999.00	14.40	2.00	0.00
Blair Road	0.52	0.24	0.01	0.04	192.50	18.00	12.00	8.89
Parksville	0.25	0.16	0.06	0.09	44.00	16.08	10.00	9.95
Steven's Creek	0.40	N/A	0.04	N/A	447.30	16.89	9.60	3.77
Big Clouds Creek*	0.30	0.15	0.31	0.27	3.18	19.75	0.04	0.00
South Fork Broad River*	0.41	0.20	0.29	0.32	542.33	46.42	0.00	10.99
Georgia Sites								

* Individidual sites from Georgia. No means necessary

Outreach and other collaborative efforts over the last year included presenting a visiting lecture on this work to students in the upstate, and production of a full page informational layout on redeye bass and related conservation concerns for the SCDNR printed Rules and Regulations book. Staff attended the Spring meeting of the Black Bass Conservation Committee in Auburn, AL where it was decided that this formerly SDAFS ad hoc committee would transition to a working group operating under the Southern Aquatic Resources Partnership (SARP) umbrella. Together with partners at Clemson University, Research and Region 1 staff submitted a proposal for continuing work to identify refuge areas of redeye bass in the Savannah Basin. Awarded funding from SARP to SCDNR totals $82,290. This will be used to fund genetic analysis of fish collected through planned Sport Fish funded activities.

Recommendations

Continue to work with Region 1 and outside partners to examine redeye bass stream populations in the Savannah Basin, to evaluate the extent of hybridization among and within stream populations, to identify refuge areas of pure redeye bass, and to prioritize stream populations and habitats for conservation. Prioritize outreach needs associated with the species. Convene a Bartram's Bass Working Group, to include but not be limited to staff from SCDNR and GADNR, to guide continued research and conservation of the species.

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Prepared By: <u>Jean K. Leitner</u> Title: <u>Biologist</u>

Job Title: Crappie Data Compilation and Evaluation

Period Covered July 1, 2015 – June 30, 2016

Summary

The compilation and management of black crappie *Pomoxis nigramaculatus* data continued. Trap net data was acquired and compiled for Lake Secession and was included in our master data base. Data from all reservoirs (Lakes Greenwood, Murray, Wylie, Wateree, and Secession) was put into a standard format in preparation for use in FAST modeling to examine growth and potential impacts of varying regulations on these fisheries.

Fish were collected in conjunction with the Crappie Masters tournament on Lake Greenwood, and through a cooperating angler on Lake Thurmond, in efforts to collect fish of larger and older age classes than typically encountered in routine trap netting. Tournament angled fish Age VI or greater numbered 77, more than eight times the number from three years of Lake Greenwood trap net sampling. Twenty of 39 fish caught from Lake Thurmond were Age VI or older, while two fish Age VI or older were collected from three years of trap net sampling. Collection of angled fish from tournaments and individual angler networks provide an excellent opportunity both for outreach and to augment our data base with older age classes. Crappie were also collected from Regions 1 and 3 reservoirs by spring electrofishing, in conjunction with routine largemouth bass sampling.

Introduction

Crappie are an economically and recreationally important sportfish in South Carolina. The species group is ranked first in number of days and second in total number of anglers based on South Carolina respondents to the 2006 National Survey of Fishing, Hunting, and Wildlife-

Associated Recreation (USFWS 2006). In addition to individual recreational anglers, a number of fishing clubs both local and national maintain active tournament schedules with frequent events on South Carolina lakes.

There are two species of crappie and both are present in South Carolina. Black Crappie is native to all South Carolina drainages and is widely distributed throughout the state. White Crappie *Pomoxis annularis* is introduced. Though established in some areas of the Piedmont and Inner Coastal Plain regions, this species remains generally rare (Rohde et al. 2009). While White Crappie are collected and recorded in South Carolina in the routine survey of crappie, their numbers are very small. All of the data reported on here is for individuals identified as Black Crappie.

Crappie are often reported to be a difficult fish to manage (Maceina and Stimpert 1998). Growth and recruitment can vary widely both among populations, and among year classes within populations (Allen and Miranda 1998, 2001). Responses to management actions can vary widely as well (Wright et al. 2015). In an effort to better understand the dynamics of crappie populations in South Carolina, we have worked to compile statewide data produced largely through our routine effort to track populations via fall trap netting. We have evaluated trap net data from the last ten years, and have explored additional sampling strategies. In the last year work has focused on the collection of fish Age VI or greater to better represent populations in the planned modeling of growth and response to various regulatory schemes.

Materials and Methods

Regional personnel provided data collected in the routine sampling of crappie. Data received included that collected via fall trap netting as well as from crappie collected during winter gillnetting and incidental to spring electrofishing for largemouth bass. Size, age and sex data were compiled from all regions into a standard format for archiving and for planned analysis using FAST software. Age for all fish was calculated in years to one decimal point (i.e. 1.3 years) by assuming an April 1 birthday for all fish.

In an effort to collect older fish we checked local and national fishing club schedules, and were welcomed to attend the weigh in for a National Crappie Masters tournament on Lake Greenwood. As this was an offsite weigh in, anglers were not allowed to keep their fish on day one of the two day tournament. Staff was present at the first day weigh in to pick up fish as well as communicate with anglers. All fish were iced and returned to our lab for processing. Length, weight and sex were recorded and otoliths removed for all fish. Otoliths were aged whole, or where necessary were cracked and polished to determine the number of annuli present.

Anglers known to be active crappie anglers on Lakes Murray and Thurmond, and familiar with the work of SCDNR, were contacted and asked to keep carcasses of crappie of 250 mm total length or larger, to augment the large fish segment of our database for these two lakes. Fish were filleted but otherwise kept intact, and held frozen for pickup. Total length was recorded and as with other collections otoliths were removed and aged whole, or cracked and polished when needed to determine the number of annuli present. Fish in these size classes were also collected when encountered incidental to routine collections of largemouth bass in the spring.

Results and Discussion

On March 4, 2016 we collected 152 crappie in conjunction with the Crappie Masters Tournament held on Lake Greenwood. Tournament fish from this effort represent 59 % of fish 250 mm total length or larger (N = 249) from Lake Greenwood (Figure 1) and 88 % of fish age 6 or older (N = 87).

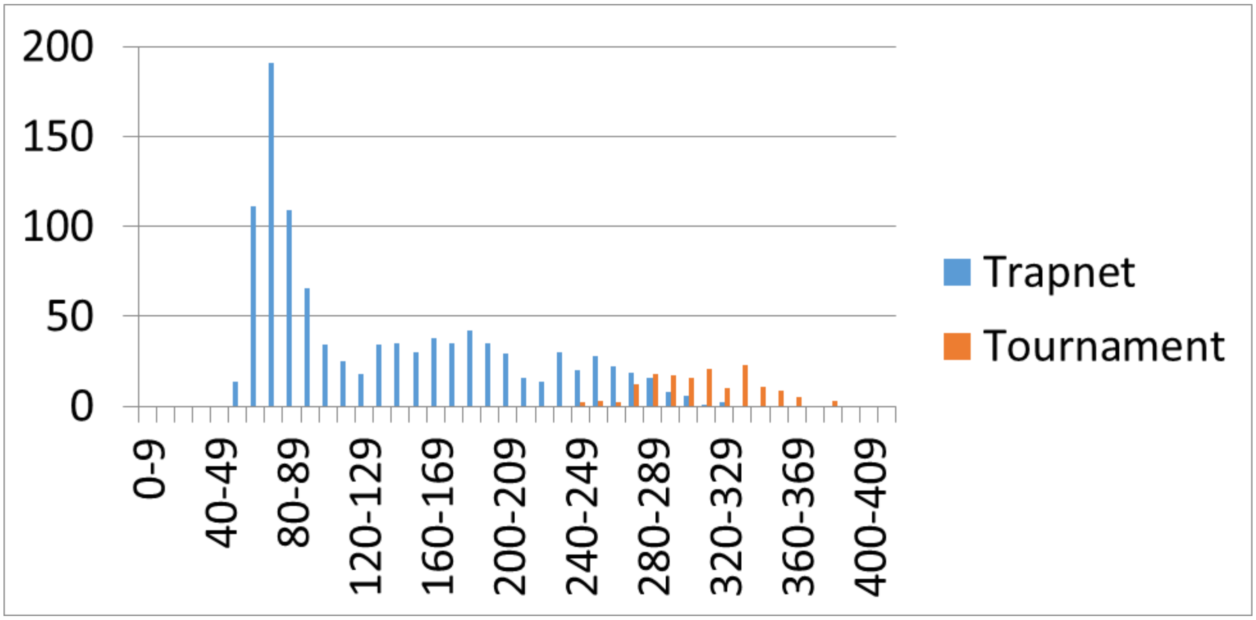

Figure 1. Crappie collected from Lake Greenwood by 10 mm tl groups. Fish were collected by trapnet (2008-2010; N=1028) and by angling (March 4, 2016 Crappie Masters Tournament; N=152).

From Lake Murray, 25 of 34 or 73% of crappie collected during spring electrofishing for largemouth bass *Micropterus salmoides* were 250 mm TL or larger, and 3 of 34 or 9% of crappie were Age VI or older. This is compared to 13% and .07 % respectively for trapnet collections (2005, 2007-20015; N = 3957). No fish were angled and kept from Lake Murray but from Lake Thurmond 39 crappie were provided by one angler. An additional 79 crappie 250 mm TL or greater were collected by electrofishing. Together these fish represent 47 % of fish 250 mm TL or larger from Lake Thurmond (N = 246) and 94 % of fish Age VI or older (N = 34).

The expansion of our database through alternate sampling strategies will be of great benefit in producing useful estimates of growth and modeling of fishery response to regulations. The incidental catch of crappie during spring electrofishing efforts offers an opportunity to augment current databases with combined field efforts. Targeted electrofishing for crappie earlier in the spring would likely prove even more effective. Carcass drop off sites have proven an effective method of obtaining data for crappie from fisheries in Florida. Our results show that even a small number of individual cooperating anglers can fill gaps in data for certain fisheries. Further, tournaments offer an opportunity to both collect large numbers of needed fish with minimal effort, and to connect with multiple anglers. These angler based collection methods may be valuable sources of both information and outreach for other species as well.

Recommendations

Continue to update compiled database with new data as it is available. Through routine trap netting efforts, and potentially additional late winter efforts, collect information on age at maturity. Assess variability in age and growth among populations and year classes, and model fishery responses to variations in regulations. Meet with regional staff to discuss findings.

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Prepared By: Jean Leitner Title: Biologist

Job Title: Summer Mortality of Striped Bass Occupying the Lower Saluda River

Period Covered July 1, 2015 – June 30, 2016

Summary

In an effort to determine total mortality of Striped Bass *Morone saxatilis* occupying the lower Saluda River during summer we initiated a telemetry study during 2016. Forty-eight Striped Bass were implanted with acoustic transmitters during May and June and their movements and fate monitored with an acoustic receiver array and by bimonthly manual tracking. As of June 30th, 41 Striped Bass were still alive within the lower Saluda River, one fish emigrated from the river, and six fish were removed from the river either by harvest or by natural mortality that resulted in their carcass being removed from the river. Five of 19 legal-sized transmitter-implanted Striped Bass were removed during May, a month when harvest is allowed.

Introduction

The Santee-Cooper system supports a naturally reproducing Striped Bass population that was overfished during the 1990's and early 2000's. The population is recovering due to more restrictive fishing regulations that include a 26" minimum length limit, a three fish creel, and a summer moratorium on fishing in the lakes to reduce catch and release (C&R) mortality. During summer nearly 50% of the Santee-Cooper spawning stock resides in the lower Saluda River, a thermal refuge that experiences intense fishing pressure where C&R fishing is allowed. When the current Striped Bass fishing regulations were enacted it was assumed that C&R mortality in the lower Saluda River would be low due to cool water temperatures throughout the summer; however, C&R and total mortality rates of Striped Bass occupying the lower Saluda River during summer are currently unknown. During FY16 we initiated a study to determine the total mortality of Striped Bass occupying the lower Saluda River during summer.

Materials and Methods

The lower Saluda River is a 16.5 km "tailwater" that flows from hypolimnetic releases at Lake Murray Dam and terminates at its confluence with Broad River forming the Congaree River. During May and June 2016 Striped Bass were collected from the lower Saluda River and surgically implanted with acoustic transmitters. Transmitters measured 53 mm long, 16 mm in diameter, and weighed 9.5 g (in water) (Model CTT-82-2; Sonotronics, Tucson, Arizona). Each transmitter operated on a single frequency between 69 and 83 KHz and had an advertised battery life of 14 months. An attempt was made to distribute transmitter implantation evenly among three sections of the river as it was expected that angler effort, and perhaps harvest, varied among sections due to the quality and quantity of angler access. Those sections were: 1. Lake Murray Dam to Corley Island (4.4 km), 2. Corley Island to I-26 (7.7 km), and 3. I-26 to the confluence of the Saluda and Broad Rivers (4.5 km) (Figure 1). Current fishing regulations allow for the harvest of Striped Bass from October 1st through May 31st; fish implanted with transmitters during May were vulnerable to legal harvest for up to three weeks, but those implanted during June were not.

All Striped Bass were collected with boat-mounted electrofishing equipment. When captured Striped Bass were immediately placed in a foam-lined cooler filled with river water, covered in wet towels, measured (mm TL [Total Length]), and sexed, when possible. Transmitters were inserted through a 40 mm incision posterior to the right ventral fin. Incisions were closed with three interrupted absorbable sutures (2-0 Maxon; Tyco Health Care). No chemical anesthesia was used; fish were sufficiently narcotized from electrofishing for the short (3-4 minute) implantation procedure. After transmitter implantation fish were immediately released near their

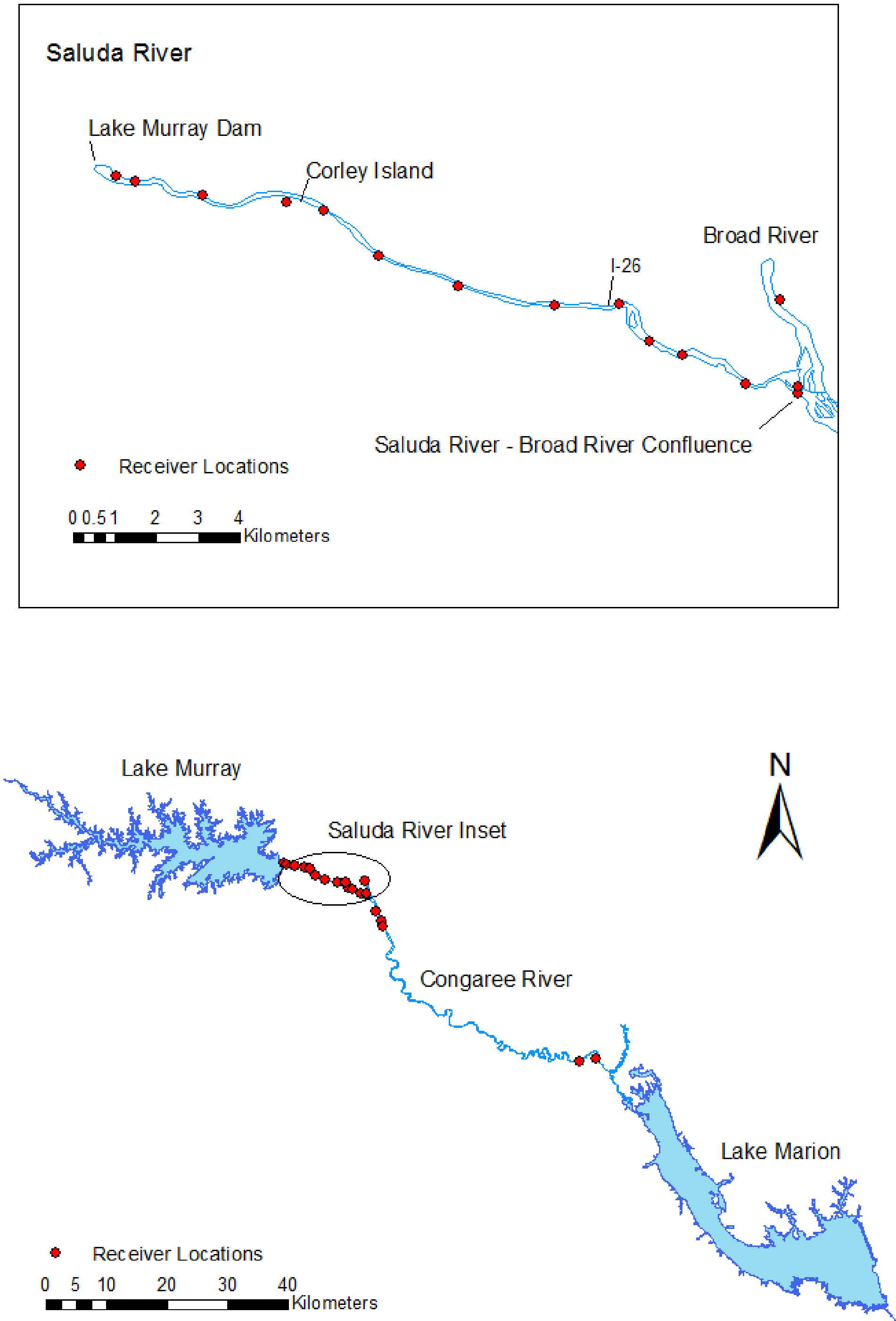

Figure 1. Sections of the Saluda River where striped bass were captured and implanted with acoustic transmitters and acoustic receiver locations used to monitor Striped Bass movements during summer 2016.

capture location. All surgical tools and tags were disinfected with Benz-All® (Xttrium Laboratories, Chicago, IL) and then rinsed with simple saline before surgery.

An array of remote acoustic receivers (SUR-3BT, Sonotronics Inc.) was used to collect movement data from transmitter-implanted fish and assess their emigration from the lower Saluda River (Figure 1). Thirteen receivers were placed in the lower Saluda River to monitor movements within the river, five receivers were placed in the Congaree River, and one receiver was placed in the Broad River to assess emigration from the system. Manual tracking of the lower Saluda River, from the Lake Murray Dam to its confluence with the Broad River, using a USR96 manual tracking kit (Sonotronics, Inc) was conducted bi-monthly during the summer to determine the fate of each fish.

We categorized the fate of each fish as: 1. Alive in the lower Saluda River, 2. Emigrated from the lower Saluda River, 3. Died within the lower Saluda River, 4. Missing from the lower Saluda River, or 5. Harvested. Fish were considered alive if they were actively moving between receiver stations, or moved while manual tracking. Fish that exited the lower Saluda River and were detected at one or more of the stations in the Congaree River were categorized as "emigrated". Fish were categorized as "dead" when they did not move between receiver locations and were consistently manually tracked in the same location. Fish were categorized as "missing" when they were no longer detected at receiver stations and were not detected in manual searches. "Missing" fish were ultimately lost from the fishery either by angler harvest or natural mortality that resulted in their carcass (transmitter) being removed from the river. "Harvested" fish were those that were reported by anglers as harvested. We made no attempt to advise anglers of the ongoing telemetry study; transmitter-implanted fish did not receive an external tag nor was the study published to the public.

Results and Discussion

Between May 5 and May 19, 2016, 32 Striped Bass were collected from the lower Saluda River and implanted with transmitters. Nineteen of those fish were > 660 mm TL and vulnerable to harvest during the month of May. Sixteen additional fish were implanted with transmitters between June 1 and June 2, 2016 (Table 1).

Table 1. Number of Striped Bass implanted with acoustic transmitters, number of legal-sized (> 660 mm TL) Striped Bass implanted, and their mean total length (range in parentheses), in three sections of the lower Saluda River during May and June of 2016

Section	N	N > 660 mm TL	Mean TL (mm)
Dam - Corley Island	16	10	682 (603 - 802)
Corley Island - I26	14	9	690 (608 - 816)
I-26 - Broad River Confluence	18	12	730 (600 - 1050)
Total	48	31	702 (600 - 1050)

As of June 30, 2016, 41 Striped Bass were alive and occupying the lower Saluda River. One fish emigrated from the lower Saluda River on May 27th, just eight days after transmitter implantation. Six fish were either reported as harvested (three fish) or went missing from the river. Those fish that went missing were not detected in manual searches or at downstream receiver locations and were likely removed from the river. Five of the six fish that were harvested or went missing were removed during May. During the month of May 19 legal-sized transmitter-implanted fish were at large in the river and 5 (26%) of those were removed from the river.

Recommendations

1. Monitoring of transmitter-implanted Striped Bass movements with manual tracking and remote receivers will continue until December 2016.
2. During 2017 we will use a multi-state capture-recapture model to estimate the total mortality of Striped Bass occupying the lower Saluda River during summer, make observations on their movements within the river, and determine emigration dates.

Prepared By: Jason Bettinger Title: Wildlife Biologist

Job Title:	Development of a Population Monitoring Plan for Broad River Smallmouth Bass
Period Covered	July 1, 2015 – June 30, 2016

Summary

During 2016 we evaluated mark-recapture techniques as a method to estimate abundance of Smallmouth Bass *Micropterus dolomieu* in the Broad River, South Carolina. In collaboration with Clemson University, the number of Smallmouth Bass in a 4.2 km reach of the Broad River was estimated using mark-recapture data from fish collected with angling and boat electrofishing gear. Clemson University staff used a closed population mark-recapture model in a Bayesian hierarchical framework to estimate 2,380 Smallmouth Bass (95 % CI: 1,578 - 3,693) > 200 mm TL in the 4.2 km study reach. Radio transmitters were implanted in Smallmouth Bass and their movements monitored by manual searches to satisfy the assumption of a closed population during the mark-recapture survey.

Introduction

A thriving fishery for Smallmouth Bass exists in the Broad River; however, due to poor river access, poor capture efficiency, and difficult navigation a suitable method to assess Smallmouth Bass abundance and population structure has not been developed. In previous years we have evaluated catch per unit effort and multiple pass depletion surveys using boat electrofishing to estimate abundance; however, those methods have not produced satisfactory results with available resources. During 2016 we initiated an evaluation of mark-recapture techniques, in collaboration with Clemson University, as potential standard sampling techniques to evaluate smallmouth bass density, biomass, and population structure.

Materials and Methods

Smallmouth Bass were captured with boat electrofishing and angling gear from a 4.2 km reach of the Broad River below 99-islands Dam on five dates between October 20 and November 11, 2015. On the first two sample dates, when stream discharge was < 1,500 ft^3/s angling was used to capture Smallmouth Bass. During subsequent samples stream discharge (>1,500 ft^3/s) was too high, and turbid, for successful angling therefor boat electrofishing was used to capture Smallmouth Bass. Both angling and electrofishing were conducted during the day typically between 10 AM and 6 PM. During angling samples fish were captured on rod and reel while ten anglers floated the river or waded in shoals. One sixteenth and 1/8 ounce inline spinner baits (e.g., rooster tails) were generally used to capture fish during angling. Angler effort was calculated as the product of time fished (h) and the number of anglers. Boat electrofishing was conducted along the shoreline and in complex mid-channel habitats (e.g., shoals) using a Smith-Root 2.5 GPP electrofishing system operating with pulsed-DC at 60 pps with 3 to 4 amps of output. Boat electrofishing effort was the total sampling time (i.e. not "pedal" or generator on time).

When fish were captured during angling and electrofishing surveys they were held in livewells (i.e., coolers filled with river water) until they could be transferred to the tagging crew, which consisted of 3 – 4 people depending on sample date, for processing. During processing each fish was measured for Total Length (TL, mm), weighed (g), checked for the presence of a passive integrated transponder (PIT) tag with a handheld reader, and implanted intraperitoneally with a PIT tag if a tag was not detected. Two models of FDX-B PIT tags were utilized that were nominally 8 x 1.4 mm and operated at 134.2 KHz (FDX-B "skinny"; Oregon RFID, Portland, Oregon and MiniHPT8, Biomark, Boise, Idaho).

To satisfy the no immigration or emigration assumption of marked and unmarked animals into or out of the study reach (closed population) a radio telemetry study that was initiated during May 2015 was continued during 2016. During May 2015, 14 Smallmouth Bass captured with boat electrofishing gear from the river section below 99-Islands Reservoir were implanted with radio transmitters (ATS F1580, Advanced Telemetry Systems, Isanti, MN). During October 2015 five additional fish collected from the same river section were implanted with radio transmitters. Transmitter-implanted fish were manually tracked at least monthly using an ATS scanning receiver (model R2000, Isanti, MN).

Clemson University staff estimated the abundance of Smallmouth Bass in the study reach using closed population capture-mark-recapture model in a Bayesian hierarchical modeling framework

<u>Results and Discussion</u>

During the mark-recapture sampling 467 individual Smallmouth Bass were collected from the study reach (Table 1). Seventeen fish were recaptured during subsequent samples and one fish was recaptured twice. Overall mean total length of Smallmouth Bass was 241 mm (range; 107 – 520 mm TL). Smallmouth Bass collected with angling gear (mean TL = 223 mm) were significantly smaller than those collected with electrofishing gear (mean TL = 261 mm) (t-Test, $P < 0.05$) largely due to the larger individuals (> 400 mm TL) collected with boat electrofishing (Figure 1).

Table 1. Date of sample, collection method, number collected (N), mean total length (TL, mm), with range in parentheses, and number of recaptured smallmouth bass collected during 2015 from the Broad River, South below 99-Islands Dam.

Date	Gear	N	Mean TL (mm)	Recaptured	Effort (h)
10/20/2015	Angling	136	217 (114 – 416)	-	70.00
10/22/2015	Angling	121	231 (123 – 403)	0	75.80
10/29/2015	Electrofishing	73	278 (121 – 505)	6	6.58
11/4/2015	Electrofishing	108	262 (119 – 513)	8	6.75
11/11/2015	Electrofishing	46	230 (107 – 520)	4	2.42
Total		467	241 (107 – 520)	18	

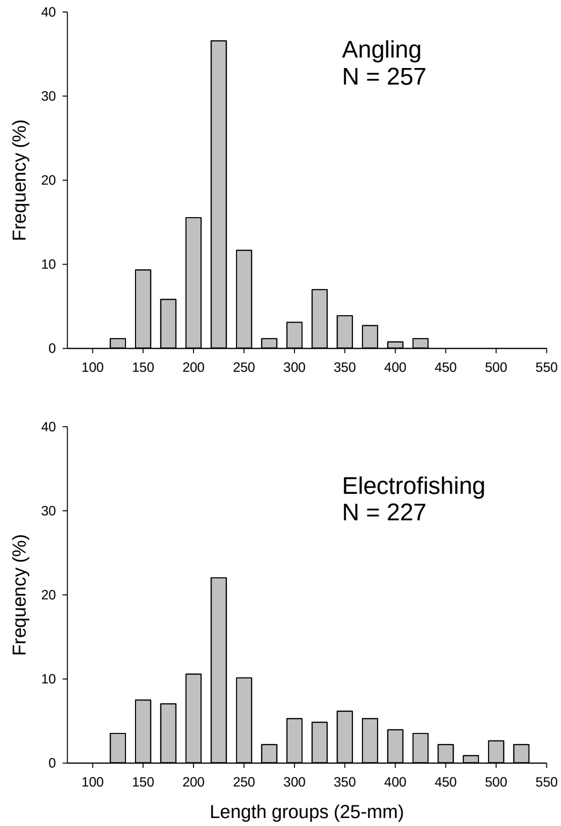

Figure 1. Length frequency distribution of smallmouth bass collected with angling gear (top panel) and boat electrofishing gear (bottom panel), from the Broad River, South Carolina during fall 2015.

Manually tracking of transmitter-implanted Smallmouth Bass indicated that closed population models were suitable for estimating abundance of Smallmouth Bass. Clemson University's initial estimate of abundance was 2,380 Smallmouth Bass (95 % CI: 1,578 - 3,693) > 200 mm TL in the 4.2 km study reach. Clemson University staff is using the data collected during the study in simulation models to determine the minimum effort needed to detect proportional (e.g., 25%, 50%) changes in Smallmouth Bass abundance. When simulations are completed we will determine whether mark-recapture sampling is a practical tool for estimating and assessing changes in Smallmouth Bass abundance.

Recommendations

Based on the results of simulation modeling make final recommendations as to the practicality of mark/recapture methods for estimating Smallmouth Bass abundance in the Broad River.

Prepared By: Jason Bettinger   Title: Wildlife Biologist

Job Title:	Assessment of condition, growth, contribution to fish community, and diet of striped bass, white perch, and American shad young-of-the-year in the Santee-Cooper lakes, South Carolina
Period Covered	July 1, 2015 – June 30, 2016

Summary

During 2016 we quantitatively evaluated diet data that was collected between 2009 and 2013 from key young-of-the-year (YOY) fishes in the Santee-Cooper lakes. There were significant differences (ANOSIM, $R = 0.956$, $p < 0.001$) among the diets of American Shad *Alosa sapidissima,* White Perch *Morone americana,* and Striped Bass *Morone saxatilis* collected from littoral areas of Lake Marion. The most important prey of white perch and small (≤ 86 mm TL [Total Length]) Striped Bass were benthic insects. Fish and surface insects were the most important prey of large (> 86 mm TL) Striped Bass and American Shad, respectively. There was significant biological overlap (Horn's index = 0.91) in the diets of White Perch and small Striped Bass indicating the potential for resource competition between these fishes depending on prey availability. The diet of American Shad, primarily feeding at the surface, did not significantly overlap (Horn's index ≤ 0.42) with Striped Bass or White Perch.

There were significant differences (ANOSIM, $R = 0.943$, $p < 0.001$) among the diets of American Shad collected from different habitats (pelagic and littoral), lakes (Marion and Moultrie), and seasons (summer and fall). The diet of American Shad collected from littoral and pelagic areas of Lake Marion during summer were similar with surface insects the most important prey in both habitats with near complete biological overlap (Horn's index = 0.99). However, in Lake Moultrie during both seasons and during fall in Lake Marion Copepods were the most important prey of American Shad collected from pelagic areas.

Introduction

'Fingerling mortality' of Striped Bass is a key issue for the Santee-Cooper Striped Bass stakeholders and it has been a key issue of the DNR for many years. Many hypotheses have been generated to define the causes of either good or poor recruitment in a given year. These hypotheses include, but are not limited to, reduction in the adult spawning stock, competition with resident and anadromous species, and reduced nutrient inflow due to drought. The Santee-Cooper Comprehensive study group of the DNR defined investigation of the 'competition for resources' hypotheses as a primary goal. In previous years we defined the growth, condition, relative abundance, and described the diet of YOY White Perch, American Shad, Striped Bass, and Threadfin Shad *Dorosoma petenense*. During 2016 we quantitatively assessed the diet of these fishes and evaluated the potential for diet overlap.

Materials and Methods

Young-of-year American Shad, Threadfin Shad, White Perch, and Striped Bass were collected at least monthly from two Lake Marion sites with boat electrofishing gear during each summer 2009 - 2012. At each site night-time electrofishing was conducted for roughly 10 minutes at each of three transects. During 2009 up to 15 American Shad, White Perch, and Striped Bass per site were fixed in 10% formalin on every electrofishing sample date to describe the diet of key species inhabiting littoral areas. During 2011 Threadfin Shad collected during nighttime electrofishing were retained to describe their diet. To describe the diet of American Shad inhabiting pelagic areas 36 American Shad collected with gillnets from Lake Marion between 7 August and 25 November 2013, and 23 American Shad collected from Lake Moultrie between 21 August and 12 December 2013 were placed on wet ice and frozen within 12-h of collection. Before processing each fish was measured (TL, mm) and weighed (g). The stomach was excised and placed in ethanol.

The stomach contents of preserved Striped Bass, American Shad, and White Perch specimens were examined under a dissecting microscope and identified to the lowest practical taxon. Larger taxa (e.g., insects) were identified and removed from the sample. When smaller taxa (e.g., microcrustaceans) were too numerous to count the sample was placed in 40 ml of water, agitated and a subsample, normally 8 ml, was extracted. The subsample was placed in a plankton wheel and all taxa enumerated. The number of each taxon was estimated by expanding the plankton wheel counts based on the volume of the subsample. Up to 15 individuals of each taxa in each stomach sample were measured with a micrometer.

Contents from the foregut (esophagus and gizzard) of Threadfin Shad were removed and stained with Eosin B. Three 1 ml subsamples were removed from the stained contents and placed on 3 individual Sedgewick-Rafter cells. The sample contents were reviewed under a compound microscope and identifiable prey items were enumerated along five horizontal transects of each Sedgewick-Rafter cell. In addition the proportion of algal cells and benthic material encountered was qualitatively assessed by percent.

Because different species and collections were preserved differently, some fish were fixed in formalin and others were placed on wet ice and later frozen, and all excised stomachs were placed in ethanol, we used dry weights to assess diet composition by weight. Dry weights for prey items were assigned, calculated, or directly measured. For larval insects, micro crustaceans, and Tessellated Darters *Etheostoma olmstedi* (the most frequently encountered fish in stomach samples) with fully intact vertebral columns we calculated dry weight using published length-weight relationships. A sample of adult insects (Midges and Mayflies) was collected from Lake

Marion during summer 2013 dried at 60ºC for 48 h, and weighed with a microbalance (Cahn, c330). Those weights were then assigned to appropriate prey items in our database. Tissue from unidentifiable fish and oligochaetes were removed from stomach samples, dried at 60ºC for 48 h, and weighed. The mean weight of each prey taxon within a stomach sample was assigned to unmeasured prey taxon within that sample.

For analysis of diet data each identified prey taxon was assigned to one of ten diet categories based primarily on their position in the water column (benthic or surface) and their taxonomic classification (Table 1). The proportion by dry weight of each diet category in individual fish stomachs was used to assess differences among the diets of each predator group. Predator groups included large (>86 mm TL) Striped Bass, small (<= 86 mm TL) Striped Bass, White Perch, and American Shad. Fish with empty stomachs and fish with less than 12 µg of diet material were removed from analysis. One-way analysis of similarities (ANOSIM; R, Vegan Package) using the Jaccard dissimilarity function were used to assess statistical differences among the diets of predator groups collected during summer shoreline sampling of Lake Marion and for American Shad collected from different habitats (shoreline vs pelagic), seasons (summer vs fall/winter) and Lakes (Marion vs Moultrie). For American Shad the summer season was defined as June to September 15, and fall was defined as September 16 through December. ANOSIM calculates the test statistic R based on the mean ranks between and within groups. The value of R ranges from -1 to 1, a value of R = 0 indicates the rank similarities are similar within and among groups (there is no difference among the groupings) a value of R = 1 indicates the samples within groups are more similar to each other than samples from other groups. ANOSIM was used as a global test to determine if diets among predatory groups were similar. Horn's index of similarity was used to examine the degree of diet overlap among the predator groups using the mean proportion by dry weight of each diet category among individuals within predator groups. Horn's index values > 0.6 indicate significant biological overlap.

Table 1. Diet categories (in bold), and the taxa assigned to each diet category, used for analysis of diet data collected from young-of-the- year fishes in Lakes Marion and Moultrie.

Benthic Crustacea	**Benthic Insect**	**Benthic Mite**	**Benthic Mollusca**	**Cladocera**
Amphipods	Coleoptera larva	Hydracarina	Bivalve	Bosminidae
Ostracods	Diptera larva		Gastropod	Chydoridae
	Diptera pupae			Daphniidae
	Odonata larva			Ilyocryptidae
	Trichoptera larva			Leptodoridae
	Mayfly nymphs			Sididae

Copepoda	**Fish**	**Surface Insect**	**Worm like**	**Other**
Calanoid	*E. flabellare*	Arachnidae	Nematodes	Bryozoan
Cyclopoid	Fish tissue	Coleoptera Adult	Oligocheates	Plant
		Dipteran Adult		Algae
		Mayfly Adult		Detritus
		Hemiptera		Sand
		Hymenoptera		
		Odonata Adult		
		Trichoptera Adult		

Frequency of occurrence (%O), percent mass (%M), percent number (%N), and percent index of relative importance (%IRI) were calculated to evaluate the importance of prey categories and individual prey taxa in the diets of each predator group using the following equations:

$$\%O_i = \frac{100O_i}{\sum_{i=1}^{n} O_i},$$

$$\%M_i = \frac{100M_i}{\sum_{i=1}^{n} M_i},$$

$$\%N_i = \frac{100N_i}{\sum_{i=1}^{n} N_i},$$

$$\%IRI_i = 100 * IRI_i \sum_{i=1}^{n} IRI_i,$$

Where *n* is the total number of prey taxa found in a predator group, M_i and N_i are the total dry mass and number of prey *i* in a predator group, respectively, O_i is the number of predator stomachs containing prey *i* in a predator group, and IRI = $\%O_i(\%M_i + \%N_i)$.

Results/Discussion

Frequency of occurrence, the number of individual stomachs containing a diet category or taxa group, indicated that benthic insects were one of the most important categories of prey among predator groups collected from summer shoreline samples of Lake Marion. The diets of more than 40% of the individuals within predator groups contained benthic insects (Table 2). Dipteran larvae were the most frequently encountered benthic insect with 38% to 98% of the individuals within predator groups containing those taxa. Ephemeropteran nymphs, primarily *Hexegenia limbata*, were found in more than 20% of small Striped Bass, White Perch, and American Shad stomachs.

Other prey categories that were commonly found in multiple predator groups included, Cladocerans, Copepods, benthic Crustacea and surface insects. Cladocerans and Copepods were found in > 40% of small Striped Bass and White Perch stomachs. Benthic Crustacea, primarily ostracods, were found in 36% of White Perch and 41% of American Shad stomachs. Surface insects, primarily dipteran adults and adult *Hexegenia limbata,* were found in 31% of large Striped Bass and 94% of American Shad stomachs. Fish were frequently encountered in the diet of small (20%) and large Striped Bass (56%). Interestingly, the only fish we were able to identify in the stomachs of Striped Bass were tessellated darters. Fish tissue was encountered in 39 Striped Bass stomachs and one White Perch stomach. Ten of the Striped Bass contained a total of 16 Tessellated Darters, all other stomachs contained unidentifiable fish tissue.

Numerically Cladocerans were the most abundant prey taxa encountered in Striped Bass stomachs accounting for 42% of the diet items in small Striped Bass and 82% of the diet items found in large Striped Bass (Table 2; Figure 1). Copepods (26% of diet items) and benthic insects (23% of diet items) were also abundant in small Striped Bass. White Perch stomachs mostly contained benthic insects (40% of diet items), and copepods (39% of diet items). American Shad stomachs mostly contained surface (60% of diet items) and benthic insects (21% of diet items). For our analysis we categorized dipteran pupae as "benthic insects"; however, it is unknown whether these insects were consumed while emerging from the surface or within the water column.

The diet by mass of most predator groups was dominated by a single prey group. Fifty-one percent (51%) of the diet of small Striped Bass consisted of fish and 92% of the diet of large Striped Bass consisted of fish. White Perch diet primarily consisted of benthic insects (82%) and American Shad diet primarily consisted of surface insects (95%).

Table 2. Percent mass (%M), percent number (%N), and frequency of occurrence (%O) for prey categories and taxa in the diets of young-of-the-year fishes collected from shoreline samples of Lake Marion.

		Striped Bass <86			Striped Bass > 86			White Perch			American Shad		
Prey Category	Prey Taxa	%M	%N	%O	%M	%N	%O	%M	%N	%O	%M	%N	%O
Benthic Crustacea	**Total**	**1%**	**1%**	**10%**	**<1%**	**1%**	**12%**	**2%**	**4%**	**36%**	**<1%**	**5%**	**41%**
	Amphipod	1%	1%	10%	-	-	0%	1%	1%	13%	-	-	0%
	Ostracod	-	-	0%	<1%	1%	12%	1%	3%	30%	<1%	5%	41%
Benthic Insect	**Total**	**35%**	**23%**	**82%**	**1%**	**4%**	**40%**	**82%**	**40%**	**98%**	**5%**	**21%**	**72%**
	Coleoptera	-	-	0%	<1%	<1%	2%	-	-	0%	-	-	0%
	Diptera	28%	21%	82%	<1%	4%	38%	65%	37%	98%	3%	19%	69%
	Ephemeroptera	1%	1%	20%	<1%	<1%	4%	13%	2%	36%	1%	2%	22%
	Odonata	-	-	0%	<1%	<1%	2%	-	-	0%	-	-	0%
	Trichoptera	6%	1%	2%	-	-	0%	5%	<1%	5%	-	-	0%
Benthic Mite	**Hydracarina**	**<1%**	**1%**	**6%**	**<1%**	**<1%**	**4%**	**<1%**	**<1%**	**3%**	**<1%**	**8%**	**48%**
Benthic Mollusca	**Total**	**<1%**	**<1%**	**8%**	**<1%**	**<1%**	**2%**	**<1%**	**<1%**	**1%**	**-**	**-**	**0%**
	Bivalve	<1%	<1%	2%	-	-	0%	<1%	<1%	1%	-	-	0%
	Gastropod	<1%	<1%	6%	<1%	<1%	2%	-	-	0%	-	-	0%
Cladocera	**Cladoceran**	**4%**	**42%**	**41%**	**1%**	**82%**	**15%**	**4%**	**17%**	**59%**	**<1%**	**4%**	**17%**
Copepod	**Copepod**	**3%**	**26%**	**45%**	**<1%**	**2%**	**17%**	**11%**	**39%**	**77%**	**<1%**	**1%**	**19%**
Rotifer	**Rotifer**	**-**	**-**	**0%**	**-**	**-**	**0%**	**-**	**-**	**0%**	**-**	**-**	**0%**
Surface Insect	**Total**	**4%**	**<1%**	**6%**	**7%**	**3%**	**31%**	**1%**	**<1%**	**1%**	**95%**	**60%**	**94%**
	Arachnid	-	-	0%	-	-	0%	-	-	0%	<1%	<1%	2%
	Coleoptera	1%	<1%	2%	-	-	0%	-	-	0%	<1%	<1%	3%
	Diptera	-	-	0%	-	-	0%	-	-	0%	10%	50%	81%
	Ephemeroptera	4%	<1%	4%	7%	3%	31%	-	-	0%	68%	6%	34%
	Hemiptera	-	-	0%	-	-	0%	-	-	0%	<1%	<1%	2%
	Hymenoptera	-	-	0%	-	-	0%	-	-	0%	16%	3%	13%
	Odonata	-	-	0%	-	-	0%	-	-	0%	<1%	<1%	2%
	Trichoptera	-	-	0%	-	-	0%	1%	<1%	1%	<1%	<1%	3%
	Unidentified	-	-	0%	-	-	0%	-	-	0%	<1%	1%	14%
Fish	**Fish**	**51%**	**1%**	**20%**	**92%**	**3%**	**56%**	**1%**	**<1%**	**1%**	**-**	**-**	**0%**
Worm like	**Total**	**<1%**	**5%**	**10%**	**<1%**	**4%**	**27%**	**<1%**	**<1%**	**2%**	**<1%**	**<1%**	**5%**
	Nematode	<1%	<1%	10%	<1%	4%	27%	<1%	<1%	1%	<1%	<1%	5%
	Oligochaeta	<1%	5%	10%	<1%	<1%	2%	<1%	<1%	2%	-	-	0%
Other	**Total**	**-**	**-**	**0%**	**<1%**	**<1%**	**6%**	**-**	**-**	**0%**	**<1%**	**1%**	**8%**
	Bryozoan	-	-	0%	<1%	<1%	2%	-	-	0%	<1%	1%	8%
	Plant Material	-	-	0%	<1%	<1%	4%	-	-	0%	-	-	0%
	Algae	-	-	0%	-	-	0%	-	-	0%	-	-	0%
	Detritus	-	-	0%	-	-	0%	-	-	0%	-	-	0%
	Sand	-	-	0%	-	-	0%	-	-	0%	-	-	0%

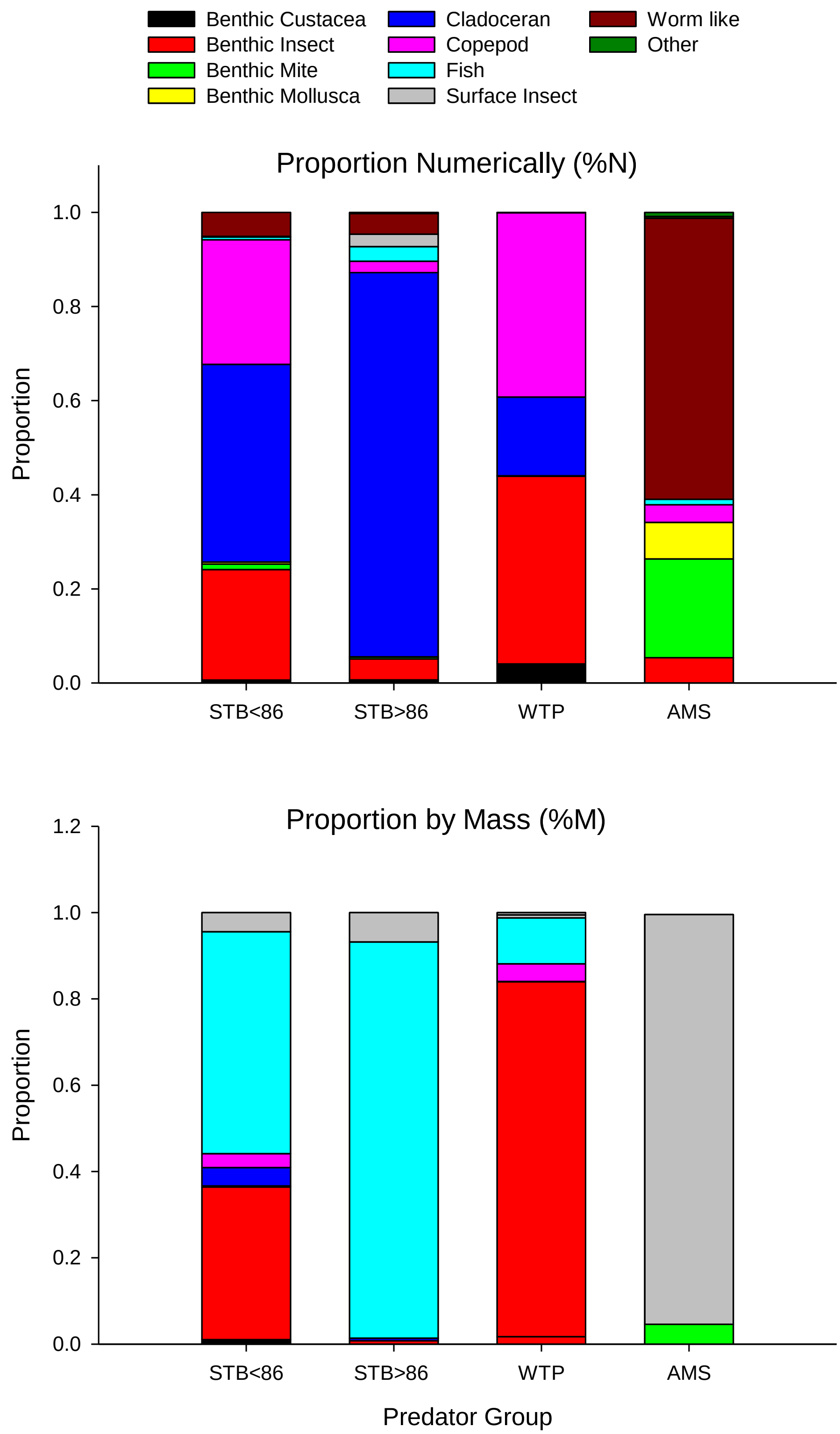

Figure 1. Proportion numerically (top panel) and by mass (bottom panel) of diet categories in the diets of small Striped Bass (<86 mm TL), large Striped Bass (> 86 mm TL), White Perch and American Shad collected from Lake Marion shoreline samples.

The index of relative importance, which uses %N, %M and %O to identify the most important prey, indicated that benthic insects were the most important prey for White Perch and small Striped Bass, while fish and surface insects were the most important prey categories for large Striped Bass and American Shad, respectively (Figure 2).

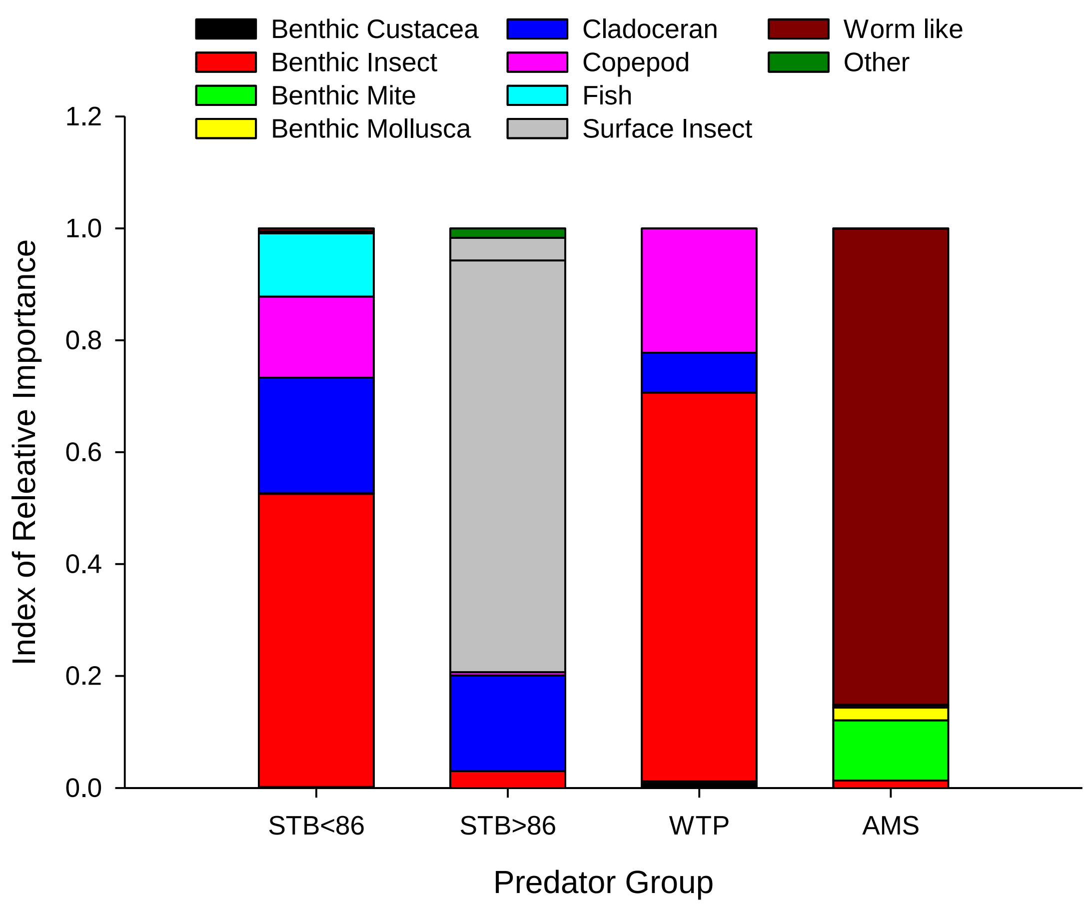

Figure 2. Index of relative importance for the diets of small Striped Bass (<86 mm TL), large Striped Bass (> 86 mm TL), White Perch and American Shad collected from Lake Marion shoreline samples.

Frequency of occurrence (%O) of prey categories in the diets of American Shad collected from both lakes and from different habitats, and seasons varied (Table 3, Figure 3). The diets of > 68% of American Shad contained surface insects except for American Shad collected from Lake Moultrie during summer where only 25% of the diets reviewed contained surface insects. Adult Diptera, Ephemeroptera, and Hymenoptera were the most frequently encountered surface insects. Benthic insects were commonly (72% of stomachs reviewed) encountered in Lake Marion shoreline samples during summer, but were less common (< 38% of stomachs reviewed) in the stomachs of American Shad collected during the other samples. Copepods and Cladocerans were frequently encountered in the stomachs of American Shad collected during fall from both lakes and during summer from Lake Moultrie. Based solely on frequency of occurrence the most important prey items of Threadfin Shad were Rotifers, Copepods, and Cladocerans. All Threadfin Shad stomachs contained algae, and most stomachs (> 90%) contained sand and benthic detritus.

Numerically surface insects were the most abundant prey taxa encountered in American Shad stomachs collected from Lake Marion during summer accounting for 60% of the diet items in shoreline samples and 64% of the diet items in pelagic samples (Table 3, Figure 3). However, in Lake Moultrie during both seasons and in Lake Marion during fall Copepods were the most abundant diet items accounting for more than 73% of the diet items encountered. Benthic insects were common in American Shad samples collected during summer (8 – 21% of diet items), but rare (<1% of diet items) during fall.

The diet by mass of American Shad collected from Lake Marion during summer was dominated by surface insects which comprised 95% of the diet of shoreline collected fish and 99% of the diet of fish collected from pelagic areas (Table 3, Figure 3). American Shad collected from Lake Moultrie during summer had a more varied diet that primarily comprised benthic insects (49%), cladocerans (17%), and copepods (14%). During fall the diet of American Shad collected from both lakes was dominated by copepods (> 60%) and surface insects (>13%).

Table 3. Percent mass (%M), percent number (%N), and frequency of occurrence (%O) for prey groups (in bold) and taxa in the diets of young-of-the-year American Shad collected from Lakes Marion and Moultrie during summer and fall, and %O for Threadfin Shad (TFS) collected from Lake Marion.

	Lake Marion									Lake Moultrie						TFS
	Summer Shore			Summer Pelagic			Fall Pelagic			Fall Pelagic			Summer Pelagic			TFS
Prey Group	%M	%N	%O	%M	%N	%O	%M	%N	%O	%M	%N	%O	%M	%N	%O	%O
Benthic Custacea Total	**<1%**	**5%**	**41%**	**<1%**	**11%**	**44%**	**<1%**	**<1%**	**47%**	**<1%**	**<1%**	**62%**	**11%**	**3%**	**25%**	**0%**
Ostracod	<1%	5%	41%	<1%	11%	44%	<1%	<1%	47%	<1%	<1%	62%	11%	3%	25%	0%
Benthic Insect Total	**5%**	**21%**	**72%**	**<1%**	**8%**	**25%**	**5%**	**<1%**	**37%**	**1%**	**<1%**	**15%**	**49%**	**17%**	**38%**	**0%**
Diptera	3%	19%	69%	1%	8%	25%	1%	<1%	32%	1%	<1%	15%	49%	17%	38%	0%
Ephemeroptera	1%	2%	22%	-	-	0%	4%	<1%	5%	-	-	0%	-	-	0%	0%
Benthic Mite Total	**<1%**	**8%**	**48%**	**-**	**-**	**0%**	**<1%**	**<1%**	**5%**	**-**	**-**	**0%**	**9%**	**1%**	**13%**	**10%**
Hydracarina	<1%	8%	48%	-	-	0%	<1%	<1%	5%	-	-	0%	9%	1%	13%	0%
Cladoceran	**<1%**	**4%**	**17%**	**-**	**-**	**0%**	**<1%**	**<1%**	**32%**	**2%**	**1%**	**31%**	**17%**	**4%**	**38%**	**29%**
Copepod	**<1%**	**1%**	**19%**	**<1%**	**12%**	**25%**	**82%**	**98%**	**79%**	**60%**	**96%**	**54%**	**14%**	**73%**	**63%**	**38%**
Rotifer	**-**	**-**	**0%**	**-**	**-**	**0%**	**-**	**-**	**0%**	**-**	**<1%**	**8%**	**-**	**-**	**0%**	**95%**
Surface Insect Total	**95%**	**60%**	**94%**	**99%**	**64%**	**69%**	**13%**	**1%**	**74%**	**37%**	**1%**	**77%**	**<1%**	**3%**	**25%**	**0%**
Arachnid	<1%	<1%	2%	0%	1%	6%	<1%	<1%	5%	<1%	<1%	8%	-	-	0%	0%
Coleoptera	<1%	<1%	3%	-	-	0%	<1%	<1%	5%	<1%	<1%	8%	-	-	0%	0%
Diptera	10%	50%	81%	8%	47%	50%	5%	1%	58%	10%	1%	54%	-	-	0%	0%
Ephemeroptera	68%	6%	34%	14%	1%	6%	4%	<1%	5%	15%	<1%	8%	-	-	0%	0%
Hemiptera	<1%	<1%	2%	-	-	0%	-	-	0%	-	-	0%	-	-	0%	0%
Hymenoptera	16%	3%	13%	77%	14%	25%	4%	<1%	11%	-	-	0%	-	-	0%	0%
Odonata	<1%	<1%	2%	-	-	0%	<1%	<1%	5%	-	-	0%	-	-	0%	0%
Trichoptera	<1%	<1%	3%	-	-	0%	-	-	0%	11%	<1%	8%	-	-	0%	0%
Unidentified	<1%	1%	14%	<1%	1%	6%	1%	<1%	11%	<1%	<1%	8%	<1%	3%	25%	0%

Table 3. continued.

	Lake Marion									Lake Moultrie						TFS
	Summer Shore			Summer Pelagic			Fall Pelagic			Fall Pelagic			Summer Pelagic			TFS
Prey Group	%M	%N	%O	%M	%N	%O	%M	%N	%O	%M	%N	%O	%M	%N	%O	%O
Nematode	**<1%**	**<1%**	**5%**	**-**	**-**	**0%**	**-**	**-**	**0%**	**<1%**	**<1%**	**8%**	**-**	**-**	**0%**	**0%**
Other Total	**<1%**	**1%**	**8%**	**<1%**	**4%**	**13%**	**<1%**	**<1%**	**47%**	**<1%**	**<1%**	**46%**	**-**	**-**	**0%**	**100%**
Bryozoan	<1%	1%	8%	<1%	4%	13%	<1%	<1%	47%	<1%	<1%	38%	-	-	0%	14%
Plant Material	-	-	0%	-	-	0%	-	-	0%	-	<1%	8%	-	-	0%	0%
Algae	-	-	0%	-	-	0%	-	-	0%	-	-	0%	-	-	0%	100%
Detritus	-	-	0%	-	-	0%	-	-	0%	-	-	0%	-	-	0%	95%
Sand	-	-	0%	-	-	0%	-	-	0%	-	-	0%	-	-	0%	91%

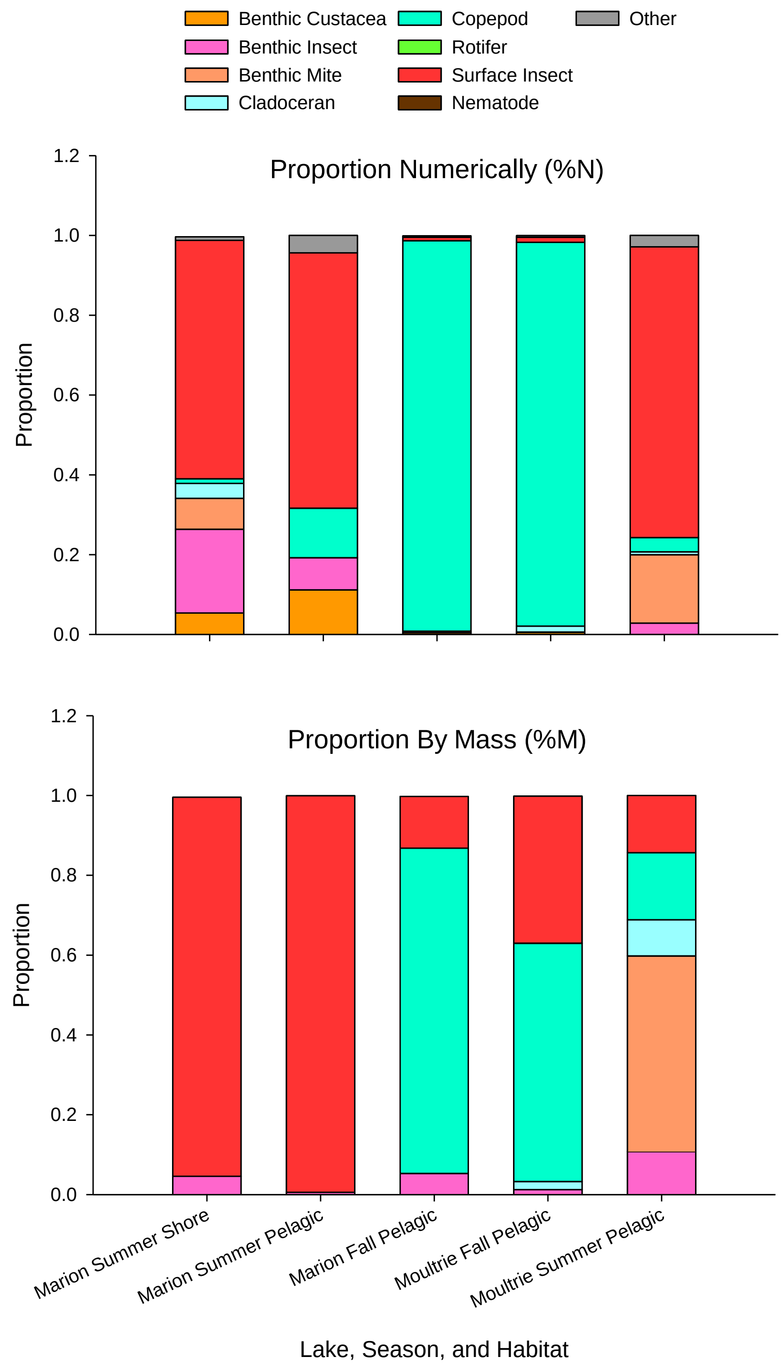

Figure 3. Proportion numerically (top panel) and by mass (bottom panel) of diet categories in the diets of American Shad collected from littoral and pelagic areas of lakes Marion and Moultrie during summer and fall.

The index of relative importance, which uses %N, %M and %O to identify the most important prey taxa, indicated that surface insects were the most important prey for American shad collected from Lake Marion during summer and Copepods were the most important prey during fall in both lakes and during summer in Lake Moultrie (Figure 4).

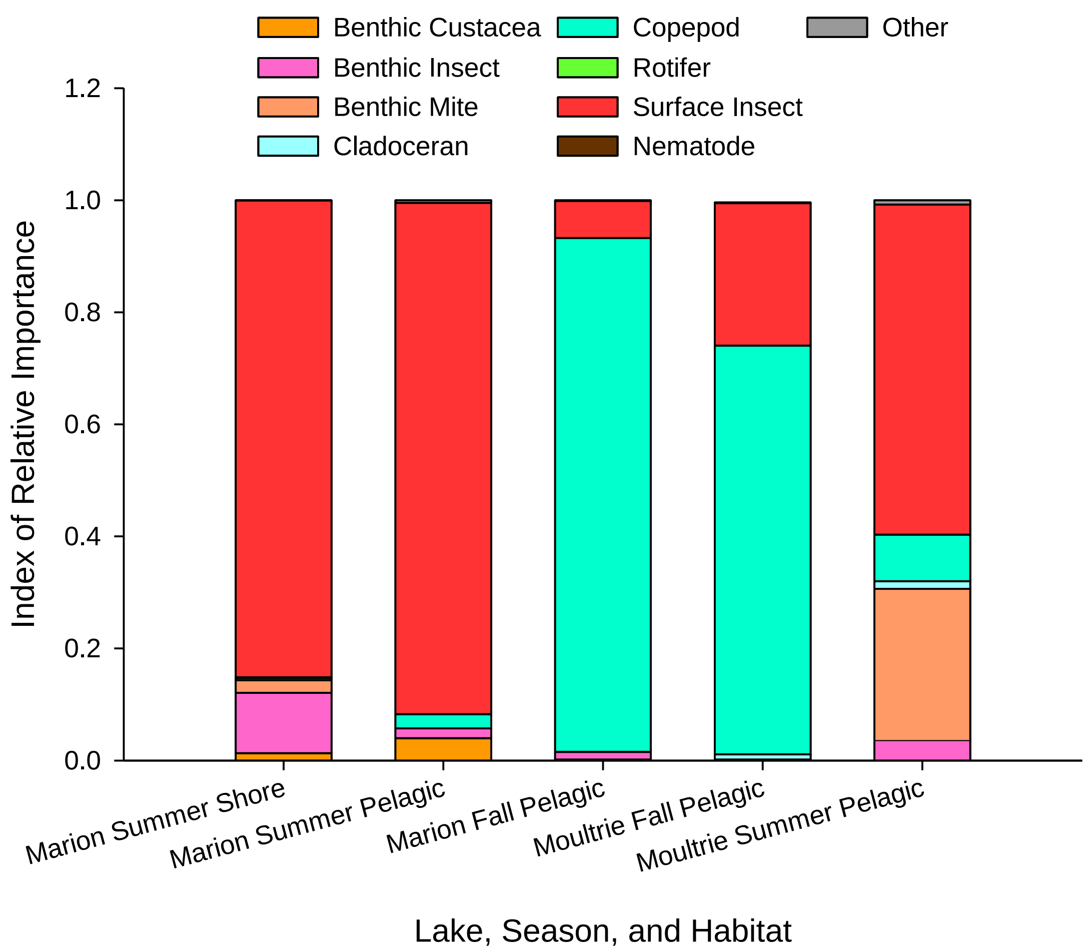

Figure 4. Index of relative importance for the diets of American shad collected from littoral and pelagic areas of lakes Marion and Moultrie during summer and fall.

There were significant differences in the diets of shoreline collected predator groups from Lake Marion (ANOSIM, R = 0.956, p < 0.001). There were also significant differences in the diets of American shad collected from the two habitats, lakes, and seasons (ANOSIM, R = 0.943, p < 0.001). Horns index of similarity resulted in significant (> 0.6) biological overlap between white perch and small (< 86 mm TL) striped bass as well as both sizes of striped bass collected from shoreline samples of Lake Marion. American shad did not have significant diet overlap with white perch or either size group of Striped Bass during summer (Table 4).

Table 4. Morisita-Horn index of niche overlap for species collected from the shoreline of Lake Marion during summer. Index values > 0.60 indicate biologically significant diet overlap. Index values calculated using the mean proportion of diet (by mass) in each prey category among individuals in predator groups.

	AMS	**STB<86**	**STB>86**
STB<86	0.27		
STB>86	0.42	0.61	
WTP	0.22	0.91	0.35

American Shad collected from different habitats, lakes, and seasons had varying degrees of diet overlap (Table 5). Nearly total overlap (0.99) occurred between shoreline and pelagic samples of American Shad collected during the summer from Lake Marion. Significant overlap (0.85) occurred between American Shad collected from pelagic areas during the fall from lakes Marion and Moultrie. There was also significant overlap between fall pelagic samples from Lake Moultrie and both habitats in Lake Marion during summer. While this overlap existed in the broader prey categories, the prey items within categories differed. For example, during summer shoreline samples adult Ephemeropterans dominated surface insect biomass, but Hymenoptera dominated the surface insect biomass of pelagic American Shad.

Table 5. Morisita-Horn index of niche overlap for American shad collected from lakes Marion and Moultrie during summer and fall from littoral and pelagic areas. Index values > 0.60 indicate biologically significant overlap. Diet proportion based on mean prey category proportion among individuals within predator groupings.

		Marion Fall Pelagic	Summer Littoral	Summer Pelagic	Moultrie Fall Pelagic
Marion	Summer Littoral	0.56			
	Summer Pelagic	0.53	0.99		
Moultrie	Fall Pelagic	0.85	0.85	0.83	
	Summer Pelagic	0.54	0.10	0.06	0.34

Recommendations

Complete final report compiling the results from the various segments (e.g., growth, condition, and diet) into a single summary report.

Prepared By: Jason Bettinger   Title: Wildlife Biologist III

Job Title: SC Small River Conservation Planning Project

Period Covered October 1, 2015 – September 30, 2016

Summary

Over the reporting period, we continued evaluating gear efficiency and commenced site reconnaissance and data collection for the Small River Assessment. Thirteen (13) sites were sampled during the reporting period within two ecobasins: Savannah Uplands and Santee Uplands.

Introduction

In South Carolina, high quality aquatic habitats support a rich fauna. The rivers and streams of the southeastern United States have the highest known diversity of mussels, snails and crayfishes in the world. In addition, freshwater fish species richness is the highest of any temperate region and the herpetofauna is globally significant. South Carolina's State Wildlife Action Plan (SWAP) contains descriptions of over 125 species of fish, herpetofauna, mussels, crayfish and snails that are directly dependent on freshwater habitats for most or all of their life-stages, accounting for approximately 40% of the state's total number of species of conservation concern (excluding marine species). The 2015 State Wildlife Action Plan (SWAP) lists 170 species (including leeches, insects, and additional species from the above listed taxa).

This project fits into a grand vision of aquatic conservation in South Carolina that focuses on landscapes and their drainage basins. The first step in building this conservation framework has been largely completed. Through previous State Wildlife Grants, small wadeable streams were assessed during the South Carolina Stream Assessment (SCSA). Data were entered into the StreamWeb database and information served in a web-accessible Stream Conservation Planning Tool. One result apparent from those data is the increase in species richness with stream size, up to the upper size limit in the sample design, which indicates that roughly one species can be expected to be added with every 10 km2 increase in stream drainage area. It also suggests that a major repository of fish diversity in the state resides in larger streams and small rivers.

The Small River Assessment is intended to extend and further the objectives of the South Carolina Stream Assessment, which was limited to wadeable streams under 150 km^2 in drainage area, in order to include the greater spatial extent of small rivers (up to 2,000 km^2).

Materials and Methods

Sampling Design

A database listing the spatial coordinates and area drained for all 100 m long segments of every stream and river in South Carolina, compiled for the Stream Assessment project, was used to create a list frame of potential sites from which to select sites for the Small River Assessment. To be included in the list frame, sites had to have a drainage area between 150 and 2000km^2 (Figure 1). Sites were stratified by major river drainage and ecoregion (=ecobasin) and by size (=drainage area). The number of sites apportioned to each strata was proportional to ecobasin area and drainage area, with three size categories defined: Class 4 – 150 to 500 km^2, Class 5 – 500 to 1000 km^2, and Class 6 – 1000 to 2000 km^2 (Table 1).

Results & Discussion

Thirteen (13) sites in two ecobasins (SAVUPL, SANUPL) were sampled during the reporting period (Table 2). Sites (length = 1 km) were sampled using one or more of the following methods as dictated by habitat types present and with target effort expended (i.e. number of replicates) in accordance with protocols established during Year 1 gear evaluations: backpack electrofishing with seine, barge electrofishing, and gill nets (evaluations detailed in report covering 2014-2015).

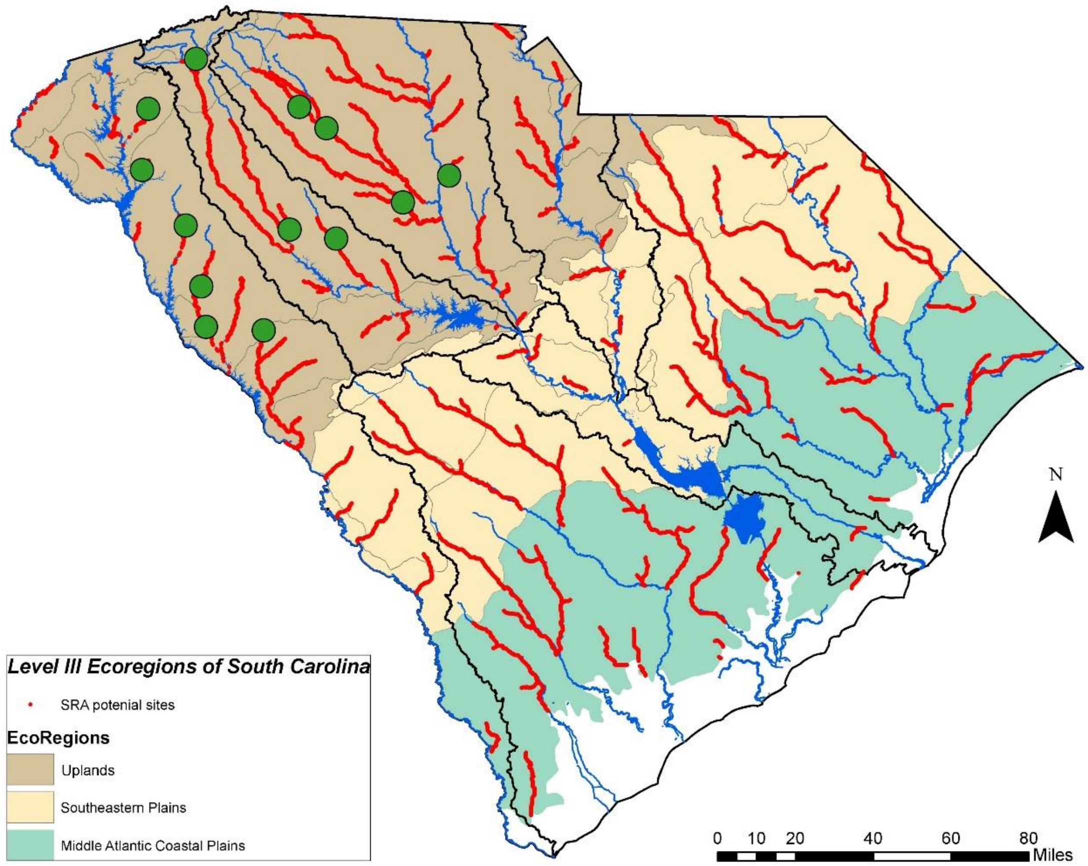

Figure 1. Occurrence of small rivers in South Carolina, defined as draining between 150 and 2000km^2 in area, are depicted in red (total length = 3,543 km). Green points map locations sampled during the reporting period.

Table 1. Breakdown of sample site allocations (n) according to ecobasin (prefixes: SAV=Savannah; SAN=Saluda, Broad, Catawba-Wateree; LS=Congaree/Lower Santee; PD=Pee Dee) and watershed size class (Class 4: 150 to 500 km^2, Class 5: 500 to 1000 km^2, Class 6: 1000 to 2000 km^2 drainage).

Ecobasin	**Drainage Area (km²)**	***n total***	***n 4***	***n 5***	***n 6***
SAVUPL	8180	11	8	3	1
SANUPL*	20178	23	16	6	3
PDUPL	711	1	1	1	1
Upland	29069	40			
SAVSEP	2555	4	3	1	1
ACESEP	5686	8	6	2	1
LSSEP*	5149	7	5	2	1
PDSEP	10210	14	10	4	2
Southeastern Plains	23601	38			
SAVFLATW	849	2	2	1	1
ACEFLATW	10637	15	11	4	2
LSFLATW	1589	3	3	1	1
PDFLATW	8805	12	9	3	2
Mid Atlantic Coastal Plains	21879	40			
Total	**74549**	**118**			

Table 2. Small River Assessment sites sampled in 2016.

Site ID	Date	Size Class	Site Name	Ecobasin	Elevation (ft)	Area (km^2)
38604	6/29/2016	4	Twelvemile Creek	SAVUPL	860	201.6
123324	7/6/2016	4	Rocky River	SAVUPL	540	278.5
80771	7/7/2016	4	Three and Twenty Creek	SAVUPL	680	187.2
204321	7/19/2016	4	Hard Labor Creek	SAVUPL	415	169.2
169080	7/27/2016	4	Little River	SAVUPL	410	380.9
202204	7/28/2016	5	Little River	SAVUPL	335	798.8
38462	11/2/2016	4	Little River	SAVUPL	700	190.7
26306	11/10/2016	4	Chattooga River	SAVUPL	1560	169.5
120002	6/28/2016	4	Rabon Creek	SANUPL	450	283.9
107072	7/20/2016	4	Duncan Creek	SANUPL	315	301.8
134474	7/26/2016	4	Little River	SANUPL	435	218.2
51726	8/3/2016	4	North Tyger River	SANUPL	515	446.8
36457	8/4/2016	4	South Tyger River	SANUPL	590	294.0
81633	8/9/2016	4	Sandy River	SANUPL	300	269.5
14073	8/16/2016	4	South Saluda River	SANUPL	940	270.1
22175	10/25/2016	4	North Saluda River	SANUPL	721	193.0

Sixty-six (66) species were collected altogether in 2016 from the SAVUPL (46 species) and SANUPL (50) ecobasins (Table 3). Data are currently being entered and analyzed to estimate occupancy, relative abundance and habitat associations of freshwater fish in South Carolina small rivers. Data will furthermore be integrated with the existing modeling framework developed from the SC Stream Assessment (2006-2011) in smaller (wadeable) streams, allowing decision support for conservation of aquatic resources.

Table 3. Fish species collected in the Small River Assessment in 2016 from the Santee Uplands (SANUPL) and Savannah Uplands (SAVUPL) ecobasins (continued on following pages). Note: The collection of Greenfin Shiner (*Cyprinella chloristia*) from the Savannah River basin represents the first known occurrence of this species in this river basin, presumably a result of anthropogenic introduction.

Family	**Scientific Name**	**Common Name**	**SANUPL**	**SAVUPL**
Aphredoderidae	*Aphredoderus sayanus*	Pirate Perch		X
Catostomidae	*Catostomus commersoni*	White Sucker	X	
	Hypentelium nigricans	Northern Hog Sucker	X	X
	Minytrema melanops	Spotted Sucker	X	X
	Moxostoma collapsum	Notchlip Redhorse	X	X
	M. macrolepidotum	Shorthead Redhorse	X	
	Moxostoma pappillosum	V-Lip Redhorse	X	
	Scartomyzon rupiscartes	Striped Jumprock	X	X
	Scartomyzon sp.	Brassy Jumprock	X	X
Centrarchidae	*Centrarchus macropterus*	Flier	X	
	Lepomis auritus	Redbreast Sunfish	X	X
	Lepomis cyanellus	Green Sunfish	X	X
	Lepomis gibbosus	Pumpkinseed	X	X
	Lepomis gulosus	Warmouth	X	X
	Lepomis macrochirus	Bluegill	X	X
	Lepomis microlophus	Redear Sunfish	X	X
	Micropterus coosae	Redeye Bass		X
	Micropterus dolomieu	Smallmouth Bass	X	
	Micropterus punctulatus	Spotted Bass		X
	Micropterus salmoides	Largemouth Bass	X	X
Clupeidae	*Dorosoma cepedianum*	Gizzard Shad		X
Cyprinidae	*Campostoma anomalum*	Stoneroller		X
	Cyprinella chloristia	Greenfin Shiner	X	X
	Cyprinella galactura	Whitetail Shiner		X
	Cyprinella labrosa	Thicklip Chub	X	
	Cyprinella nivea	Whitefin Shiner	X	X
	Cyprinella pyrrhomelas	Fieryblack Shiner	X	
	Cyprinella zanema	Santee Chub	X	
	Hybognathus regius	E. Silvery Minnow	X	X
	Hybopsis hypsinotus	Highback Chub	X	
	Hybopsis rubrifrons	Rosyface Chub	X	X
	Luxilus coccogenis	Warpaint Shiner		X
	Nocomis leptocephalus	Bluehead Chub	X	X

Family	Scientific Name	Common Name	SANUPL	SAVUPL
	Nocomis micropogon	River Chub		X
	Notemigonus crysoleucas	Golden Shiner	X	X
	Notropis chlorocephalus	Greenhead Shiner	X	
	Notropis cummingsae	Dusky Shiner	X	
	Notropis hudsonius	Spottail Shiner	X	X
	Notropis leuciodus	Tennessee Shiner		X
	Notropis lutipinnis	Yellowfin Shiner		X
	Notropis petersoni	Coastal Shiner		X
	Notropis procne	Swallowtail Shiner	X	
	Notropis scepticus	Sandbar Shiner	X	X
	Notropis spectrunculus	Mirror Shiner		X
	Semotilus atromaculatus	Creek Chub	X	X
Esocidae	*Esox americanus*	Redfin Pickerel	X	
	Esox niger	Chain Pickerel	X	X
Ictaluridae	*Ameiurus brunneus*	Snail Bullhead	X	X
	Ameiurus catus	White Catfish	X	
	Ameiurus platycephalus	Flat Bullhead	X	X
	Ictalurus punctatus	Channel Catfish	X	X
	Noturus gyrinus	Tadpole Madtom		X
	Noturus insignis	Margined Madtom	X	X
	Noturus leptacanthus	Speckled Madtom		X
Lepisosteidae	*Lepisosteus osseus*	Longnose Gar	X	
Moronidae	*Morone americana*	White Perch	X	
	Morone saxatilis	Striped Bass	X	
Percidae	*Etheostoma brevispinum*	Carolina Fantail Darter	X	
	Etheostoma hopkinsi	Christmas Darter		X
	Etheostoma inscriptum	Turquoise Darter		X
	Etheostoma olmstedi	Tessellated Darter	X	X
	Etheostoma thalassinum	Seagreen Darter	X	
	Perca flavescens	Yellow Perch	X	X
	Percina crassa	Piedmont Darter	X	
	Percina nigrofasciata	Blackbanded Darter	X	X
Poeciliidae	*Gambusia holbrooki*	Eastern Mosquitofish	X	X
		TOTAL	**50**	**46**

Recommendations

This report covers the second year of the Small River Assessment (first year of full data collection). Data are currently being entered and analyzed in collaboration with Clemson University to estimate occupancy, relative abundance and habitat associations of freshwater fish in South Carolina small rivers. Data will furthermore be integrated with the existing modeling framework developed from the SC Stream Assessment (2006-2011) in smaller (wadeable) streams, allowing decision support for conservation of aquatic resources. Sampling will continue in all ecobasins as defined in the study design.

Prepared By: Kevin Kubach, Mark Scott, Drew Gelder, Kenson Kanczuzewski

Title: Wildlife Biologists

Job Title:	Development and implementation of an environmental DNA (EDNA) monitoring tool for Blackbanded Sunfish populations in South Carolina and Georgia with determination of relative abundance, genetic health, and connectivity of extant populations
Period Covered	October 1, 2015 – September 30, 2016

Summary

As part of Multi-State Wildlife Grant SC-U2-F14AP00997, we commenced data collection for a study developing an environmental DNA (eDNA) monitoring tool for a species of conservation concern, Blackbanded Sunfish (*Enneacanthus chaetodon*). These statements summarize work done by FWF Research Staff on the project during the report period; additional accomplishments by MRD and GADNR collaborators can be found in the 2016 SWG Interim Report for the project.

Introduction

The intent of our project is to provide a comprehensive and proactive assessment of *Enneacanthus chaetodon* distribution, relative abundance, and genetic health of SC and GA populations. We will achieve our goal through the development and application of a new eDNA tool combined with traditional surveys and population genetics. The specific project objectives and their quantifiable metrics include:

1) develop and test an eDNA detection tool for *E. chaetodon*: number of primers tested, number of species amplifying with primers, completion of laboratory experiments, eDNA sampling of four known *E. chaetodon* locations, analysis of test results to determine optimal eDNA sampling protocols.

2) use the eDNA tool to conduct field surveys in appropriate *E. chaetodon* habitats throughout SC and GA.

Materials and Methods

Freshwater Fisheries staff time was devoted to Objective 2, field surveys of appropriate *E. chaetodon* habitats in SC. We collected water (eDNA) samples and habitat characterization data at 30 sites across the Sand Hills and Atlantic Southern Loam Plains ecoregions (all river basins) of South Carolina, following protocols developed during Year 1 of the study. Our field protocol was developed in conjunction with MRD and GADNR staff to ensure standardized procedures. During the eDNA survey, water quality characteristics are documented at the site level and comprise water temperature, pH, dissolved oxygen, conductivity, turbidity, and water color. A total of 20 replicate 2 L surface water samples are collected across all of the sample sites. Decimal degree GPS coordinates, time of sampling, substrate type, depth, current velocity, debris type, photos, and vegetation type are documented within a 1 meter grid at all 20 individual water sampling locations. Water body widths are measured at every 5th replicate water sample taken at each site. All water samples are taken prior to disturbing the area and caution is taken not to cross contaminate samples within a site and samples between sites. All materials which are to contact water at a site prior to water samples being taken (waders, boots, etc.) are decontaminated with 10% bleach and rinsed with DI water between each site.

Additional methodologies for the study are found in the Freshwater Fisheries Research annual progress report covering the period 01 October 2014 – 30 September 2015, as well as the SWG Interim reports by SCDNR-MRD.

Results and Discussion

Water (eDNA) and habitat data were collected at 30 sites (26 randomly selected and 4 historic *E. chaetodon* localities) across the Sand Hills and Atlantic S. Loam Plains ecoregions of South Carolina, across all river basins (Figure 1). Data analysis is ongoing; however, thus far in

South Carolina, positive detections for *E. chaetodon* have been confirmed at 5 of 13 sites analyzed (38.4%; Figure 1).

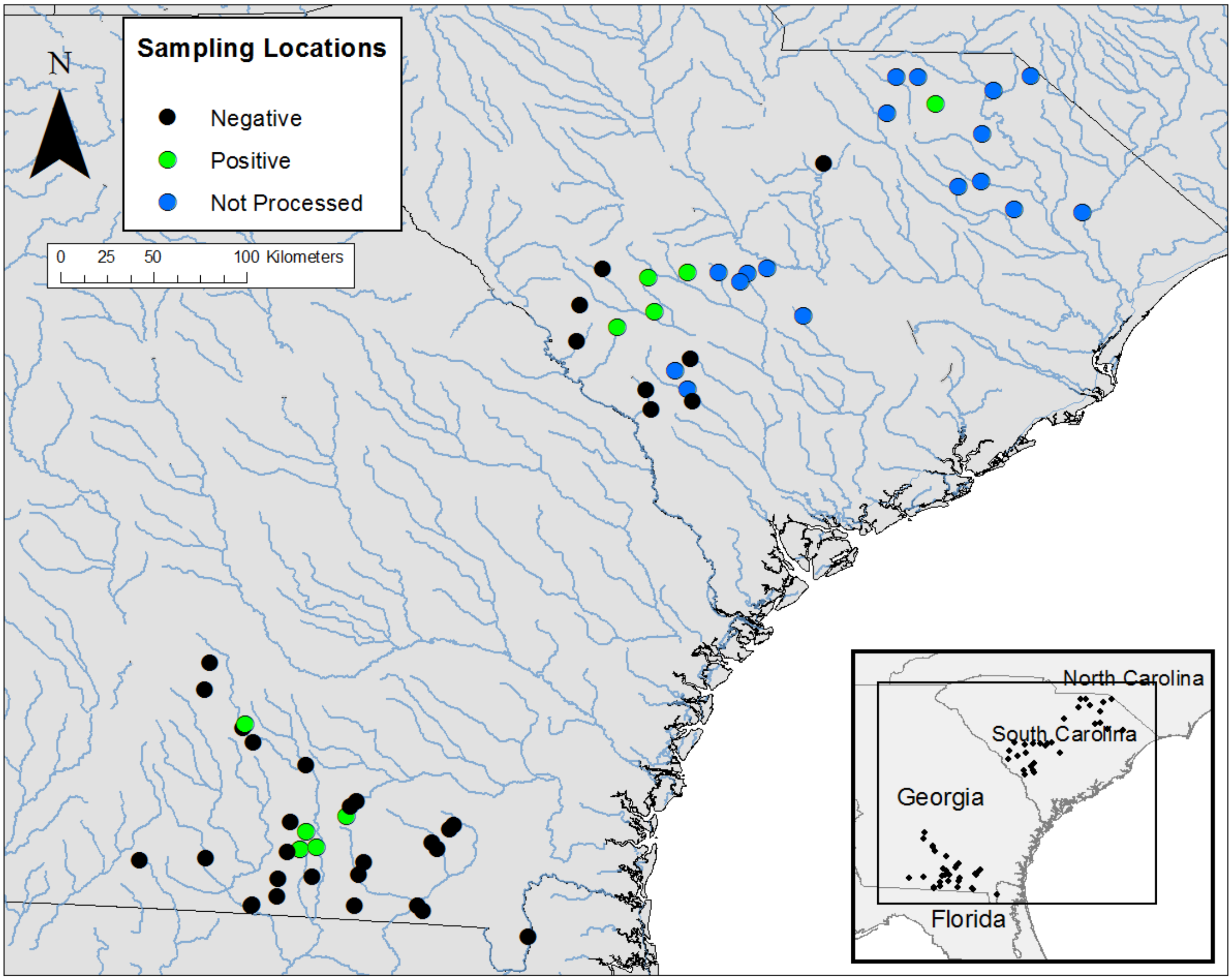

Figure 1. Environmental DNA (eDNA) and habitat sample sites in Georgia and South Carolina, showing results of eDNA analysis for *E. chaetodon* as of 15 November 2016. Map provided by M. Walker and T. Darden, SCDNR-MRD.

Recommendations

This report covers Year Two of a three year grant; we recommend the project continue as outlined in the proposal.

Prepared By: Mark Scott, Kevin Kubach, Drew Gelder, Kenson Kanczuzewski

Title: Wildlife Biologists

Job Title: Fish community response to dam removal in Twelvemile Creek, Pickens County, South Carolina

Period Covered July 1, 2015 – June 30, 2016

Summary

This progress report summarizes work done during the report period. Complete samples according to standardized methods described below were obtained in Fall 2015. The study is ongoing through 2016.

Introduction

Dams alter riverine environments by converting lotic habitats to lentic ones, thereby altering physical habitat, flow-regimes, temperature-regimes, sediment transport, dendritic connectivity, and nutrient cycling (Bednarek 2001). As a consequence, dams change the composition, structure, and function of native fish communities (Martinez et al. 1994, Taylor et al. 2001, Santucci et al. 2005). Few evaluations of the ecological effects of dam removal have been conducted in North America due to the lack of opportunity, particularly in the Southeast. A rare opportunity has presented itself with the removal of two mainstem dams on Twelvemile Creek, Pickens County, South Carolina (Figure 1).

Twelvemile Creek was extensively polluted with PCBs originating from a capacitor manufacturing plant from 1955-1975; the waste site and its receiving waters were listed with the EPA Superfund Program in 1990. Under CERCLA statute (Superfund law), a natural resources board of trustees is authorized to act as trustees of natural resources on behalf of the public, and within that role they may assess and recover damages for injuries and losses to natural resources caused by a hazardous waste site. As part of the settlement for damages caused by PCB

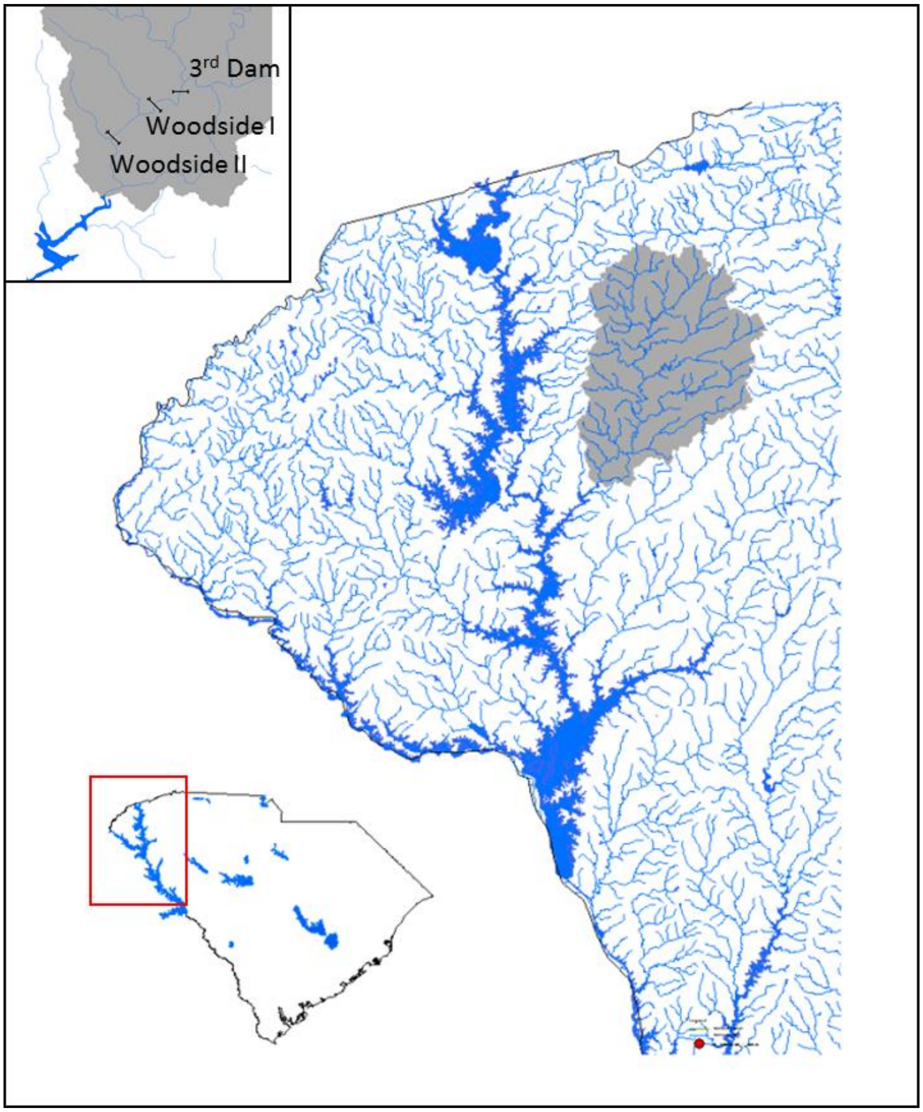

Figure 1. Twelvemile Creek drainage shaded in gray. Inset shows location of two former mainstem dams (Woodside I and Woodside II), and the remaining third dam (Easley-Central Dam).

contamination, a natural resources board of trustees facilitated the removal of two mainstem dams on Twelvemile Creek in order to 1) remove any remaining contaminated sediments that have accumulated behind the dams, and 2) to promote sediment transport to further ‘cap’ contaminated sediments downstream and in Lake Hartwell. Dam removal began in August 2009 with the initial dredging behind the upper dam (Woodside I); this dam was completely removed by April 2011. Dredging and removal preparations on the lower dam (Woodside II) began in April 2011, and removal was completed in September 2011.

The objective of this investigation was to document changes in the fish communities of Twelvemile Creek before and after the removal of the two dams (Woodside I and Woodside II). We have been monitoring fixed stations since 2006, and are scheduled to complete the study in 2016.

<u>Materials and Methods</u>

Six sampling stations were established for collecting biological and habitat data (Figure 1). The sampling stations are distributed as follows: 1) an alluvial stream section downstream of Woodside II Dam (Twelvemile Lower), 2) a bedrock-constrained free-flowing stream section downstream of Woodside II Dam (Woodside II Below), 3) an impounded area above Woodside II Dam (Woodside II Above), 4) a bedrock-constrained free-flowing stream section downstream of Woodside I Dam (Woodside I Below), 5) an impounded area above Woodside I Dam (Woodside I Above), and 6) an upstream reference station located upstream of both Woodside I and II, as well as upstream of a third dam (Robinson Bridge; Figure 1).

In addition, two sites on a nearby stream that has not been modified by dams, Three & Twenty Creek, were also established as additional reference. Fishes were collected at 20 wadeable stream segments of approximately 15m^2 within 300m segments at each site with a standardized effort using electrofishing gear and seines. All fishes encountered were collected, field identified to species level, recorded, and released. Habitat measurements of depth, velocity, and substrate were recorded at each of the 20 replicates; average widths were recorded at each site.

Results and Discussion

Total numbers of fish collected in Fall 2014 are shown in Table 1. Fall 2015 collections are shown in Table 2.

Recommendations

We will continue standardized sampling according to schedule at Twelvemile Creek and Three and Twenty Creek to provide a multi-year record of post dam-removal ecological conditions.

Literature Cited

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Table 1. Summary of fish species and numbers collected in Twelvemile and Three and Twenty Creeks in Fall 2015.

Species\Site	Robinson Bridge	Woodside I Above	Woodside I Below	Woodside II Above	Woodside II Below	Twelvemile Lower	3&20 LaFrance	3&20 Burns Bridge	Total
Blackbanded Darter	9	15	14	5	14	6	8	6	77
Bluehead Chub	2	21	24	13	13	7	14	23	117
Bluegill	1	0	1	12	19	20	12	13	78
Channel Catfish	0	0	0	0	0	11	0	0	11
Eastern Silvery Minnow	0	2	2	65	1	21	0	1	92
Flat Bullhead	0	0	1	0	0	0	1	0	2
Flathead Catfish	0	0	0	0	0	1	0	0	1
Green Sunfish	2	0	0	1	1	0	0	9	13
Largemouth Bass	0	0	0	0	2	1	0	4	7
Margined Madtom	0	3	1	5	0	0	5	2	16
Northern Hog Sucker	9	57	30	17	10	22	8	17	170
Notchlip Redhorse	0	0	0	0	0	4	0	0	4
Redbreast Sunfish	3	0	1	0	1	2	4	3	14
Redeye Bass	0	0	3	2	0	0	0	2	7
Redeye Bass x Spotted Bass	0	0	1	0	0	0	0	1	2
Roseyface Chub	0	4	3	0	0	0	1	0	8
Snail Bullhead	1	17	24	5	1	0	0	2	50
Spotted Bass	0	0	0	0	0	3	0	0	3
Speckled Madtom	0	0	0	0	0	0	4	0	4
Striped Jumprock	0	0	0	0	0	1	0	20	21
Spottail Shiner	0	7	15	110	58	80	15	46	331
Turquoise Darter	0	17	22	0	7	0	0	0	46
Warmouth	0	0	0	0	0	0	0	1	1
Whitefin Shiner	14	7	6	13	40	61	0	10	151
Yellowfin Shiner	0	30	35	3	5	3	12	5	93
Yellow Perch	0	0	0	0	0	0	1	0	1
Total Individuals	41	180	183	251	172	243	85	165	1320
Taxa Richness	8	11	16	12	13	15	12	17	28

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Job Title:	Developing sediment management guidelines to enhance habitat and aquatic resources in the Broad River Basin, South Carolina
Period Covered	July 1, 2015 – June 30, 2016

Summary

All work related to this multi-year project was completed during the reporting period. A summary of FWF-related activity and results is provided below; the full completion report can be provided upon request.

Four biological metrics showed statistically significant reductions associated with measures of suspended and bed sediment. We examined catch rates of all fish, fish species richness, catch rates of sediment-sensitive fish species, and relative abundance of sediment-sensitive macroinvertebrate taxa in relation to tributary mean annual sediment yield, mean suspended sediment concentration (SSC) in mg/L, median bed particle diameter (d50), 90th percentile bed particle diameter (d90), percent fine sand, and percent cobble substrate, in addition to other habitat variables.

Sediment-sensitive fish and macroinvertebrates were consistent in identifying a threshold level of suspended sediment in the vicinity of 20 mg/L, above which abundance of those organisms was reduced.

Three separate biological metrics (sediment-sensitive fish and macroinvertebrates, as well as total numbers of fish) were in agreement indicating a threshold in d50 of around25 mm, indicating that coarser substrates supported greater numbers of sensitive taxa.

We found significant relationships between both SSC and bed d50 with watershed factors, revealing threshold values corresponding with land use in the Broad River basin. Mean suspended sediment concentrations were elevated below a threshold of 70% forest cover in the watershed,

and SSC increased as agricultural land use exceeded about 25%. In a notable similarity, where forest cover was less than 70%, finer median bed particle sizes were more prevalent. Substrates were again finer as agriculture exceeded 25% of watershed area. Percent urban in the watershed had a threshold effect on d50 at 10% exceedance, with finer substrates occurring at greater urban extent. The 10% urban threshold is consistent with research elsewhere documenting effects of urban land use on aquatic ecosystems.

Introduction

The health of the aquatic ecosystem is directly dependent on sediment movement through the Broad River watershed. Many native upland fish species (e.g., Robust Redhorse *Moxostoma robustum*, V-lip Redhorse *Moxostoma pappillosum*) rely on relatively clean gravel and rubble shoals for spawning; however, these habitats are often degraded owing to excess sedimentation. Many rivers of the southeastern Piedmont carry and store large quantities of legacy sediment from post-European settlement, and while the Broad River is no exception, present day land-use practices, urbanization, and in-stream activities in the watershed likely contribute significant amounts of newly eroded sediment to the river and its tributaries each year. The primary objectives of this study are to: (1) quantitatively define the major paths of sediment transport, identify the physical conditions responsible for eroding, mobilizing and depositing sediment, and evaluate methods to reduce sediment input; (2) define near-field sediment transport dynamics in relation to sand-mining operations to identify best management practices for in-stream mining activities; and (3) define the relation between aquatic communities and changes in physical habitat.

Materials and Methods

Our objectives were met through extensive field surveys and collection of biological, hydrological, and geomorphic data as well as rigorous laboratory and GIS analyses over a four-year period. Eleven (11) major tributaries of the Broad River in South Carolina were selected to represent the spectrum of sediment levels and conditions. Tributary sites were sampled for fish and aquatic habitat in spring 2013, fall 2013, spring 2014 and fall 2014. Due to extremely above-average rainfall and resulting high flows during periods of 2013, some sites remained too high for sampling in certain seasons; these sites were: Pacolet River (spring 2013, fall 2013, spring 2014), Tyger River (spring 2013), Enoree River (spring 2013) and Buffalo Creek (spring 2013).

Sites were sampled using backpack electrofishing to assess the entire fish assemblage (species composition and relative abundance). Given the large size of most sites, fish sampling was accomplished by using 20 seine sets distributed throughout the sample section and among habitats in proportion to the amount of area represented by each habitat type (e.g. riffles/shoals, runs, pools). Sample sections ranged from 100 – 300 m in length, depending on the distance necessary to represent all habitat types. At each seine set location, a 3.05-m (10-ft) seine was placed at the downstream end of each habitat unit and an area of 15 m^2 was sampled immediately upstream of the seine by a single backpack electrofisher, working all fish downstream to the seine for capture. All fish were identified to species and enumerated at each set, providing a measure of fish assemblage composition by habitat units as well as by site. To ensure that fish were not recaptured in multiple set locations, fish were retained in flow-through cages until the completion of the entire sample.

In addition, habitat samples were obtained at each set in collaboration with SCDNR/South Carolina Geological Survey staff to provide a detailed measure of substrate and sediment characteristics of each site. Depth (m) and current velocity (m/s, measured 60% from surface) were measured at one point centrally located within the set area, and primary inorganic and organic substrate presence and type (woody debris) were recorded. Water quality was measured prior to each sample to ensure conditions were representative among sites and samples (temperature, dissolved oxygen, conductivity, pH and turbidity).

Analysis of relationships among sediment and biological assemblages was performed at three primary scales to evaluate spatio-temporal patterns in these relationships and allow comparison of biological responses across scales. The scales employed were:

Site – Biological and physical data pooled within each of the 11 sites (across samples).

Sample (= site x date) – Biological and physical data treated within visits to a given site.

Set – Individual fish sets (n = 20 per sample) and macroinvertebrate quadrats (n = 3 per sample) within each sample treated independently.

Results and Discussion

Previous research indicates that excessive fine sediment, both suspended in the water column and deposited on the streambed, is one of the major threats facing aquatic ecosystems (Waters 1995, Richter et al. 1997), and that human activities in the watershed are associated with increased sediment in streams and rivers (Scott et al. 2002, Grudzinski et al. 2016). A range of impacts has been observed across various functional and taxonomic groups of aquatic organisms in regards to sedimentation, but generally a decrease in habitat quality and changes in sediment loads associated with land use change alters both fish and macroinvertebrate communities (Rapport and Whitford 1999, Soulsby et al. 2001, Sutherland et al. 2002, Schwartz et al. 2011, Simpson et al. 2014). Broad River tributaries experiencing higher suspended sediment concentrations and finer channel substrates supported significantly fewer species, lower total numbers of fish, lower numbers of sediment-sensitive fish, and lower relative abundance of aquatic macroinvertebrates than streams with less sediment. In addition, we identified threshold values for these effects. The identification of threshold responses is useful in establishing targets for protection of ecological integrity, and thus inform management decisions in the conservation of natural resources (Groffman et al. 2006, Dodds et al. 2010).

Suspended sediment concentrations have been shown to affect biota both through direct damage to tissues and through indirect effects such as habitat homogenization (see Waters 1995). Sutherland (2002) found in experimental manipulations of SSC in laboratory mesocosms that increasing mean values above 25 mg/L resulted in significantly reduced fish eggs spawned, quite consistent with our threshold level. Newcombe and Jensen (1996) reviewed evidence from experimental microcosm studies on coldwater (i.e., clear water) fish species to develop a "severity of effects" scale based on concentration and duration of exposure. They reported sub-lethal effects of 20 mg/L SSC at 1-2 days exposure duration for early life-stage fish and aquatic macroinvertebrates, although their methods have been questioned as to applicability in natural systems (Diehl and Wolfe 2010). We are not aware of published research relating extensively-measured SSC to biological communities at the same locations. Our results from sediment-sensitive fish and macroinvertebrates were consistent in identifying a corresponding threshold level of mean suspended sediment in the vicinity of 20 mg/L, above which abundance of those organisms was reduced.

Bed substrate particle size is a well-known factor limiting salmonid spawning success and macroinvertebrate assemblages (Bryce et al. 2010, Soulsby et al. 2001, Waters 1995). Rabeni et al. (1995) suggested that fines ≤2mm should not exceed 10% by mass in order to support sensitive functional groups of macroinvertebrates. Our data indicated that percent sand (≤0.2mm) determined from pebble counts should not exceed 30% to support sediment-sensitive macroinvertebrates. We found agreement across fish and invertebrate taxa for a threshold in median bed particle size of around 25 mm, indicating that coarser substrates were more supportive of sensitive fish, total numbers of fish, and sensitive macroinvertebrates.

If disturbance thresholds due to landscape factors can be quantified, recommendations can be made to land managers, city/county planners, and other decision-makers to incorporate into local policies that will sustain the ability of natural systems to support native species and ecological integrity (Bretts et al. 2007, Brenden et al. 2008). We found significant relationships between both suspended and bed sediment with watershed factors, revealing threshold values with land use in the Broad River basin. Mean suspended sediment concentration dropped off as forest cover in the watershed fell below 70%, and increased as agricultural land use exceeded about 25%. In a remarkable similarity, median bed particle size also coarsened as forest cover exceeded 70%, and was finer as agriculture exceeded 25%. Percent urban had a threshold effect on d50 at 10% exceedance, consistent with other findings (Booth and Jackson 1997).

The amount of effort and resources expended to gather the data to support these findings was great, and involved essentially all major tributaries of the Broad River. This still left a rather small number of observations for site-level statistical analyses, so caution must be retained in viewing site-level results. Certainly, additional work that expanded the number of sites, such as a finer-scale selection of watersheds, would improve confidence in the results. Nonetheless, because of the consistency of findings across taxa and corroboration through time with the sample-to-sample data in this study, we recommend that these threshold values be considered representative of the effect of landscape-derived sediment in the basin.

Recommendations

Future work building on the results of this study are presented below:

We recommend that the three thresholds that emerged from the ecological relationships with sediment (forest, 70%; agriculture, 25%; urban, 10%) be mapped for catchments throughout the Piedmont Broad River drainage to produce a status map of three classes of catchments corresponding to 1) beneath, 2)near, or 3) exceed the thresholds we identified as being protective of sensitive aquatic life.

We recommend that a decision tool be implemented that would allow users to manipulate land use class values to a) determine how much mitigation/restoration in a given catchment is necessary to meet the thresholds, or b) determine how a proposed project or disturbance would affect the threshold status of the tributary. These effects can be projected downstream to receiving catchments for cumulative assessment.

We recommend that consideration be given to a future study that expands upon our work by working at a finer scale so that one of the current weaknesses can be addressed, namely the number of tributaries observed. This could be achieved by selecting smaller tributary watersheds in the basin, thereby increasing sample size and power in subsequent analyses.

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